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BOMBARDIER SINGLE-CYLINDER MEDIUM-SPEED RESEARCH ENGINE AND TEST FACILITY - PHASE III

QUALIFICATION

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17. Abstract

This report covers the third phase of the Bombardier Single-Cylinder Research Engine Program supported by the Transportation Development Centre. Earlier phases were the design of the engine and test facility and the manufacturing and installation of the single-cylinder engines with their related test cells. The work described is that which was necessary to bring the test facility to operational status, consisting of a series of studies to qualify the engines and facility for precision research and development. In addition, the computer data acquisition system, fuels and lubricants laboratory, and the turbocharger test cell are described. Some results of the qualification and multi-cylinder correlation are given.

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17. Résumé

Ce rapport traite des travaux de la troisième phase du programme de développement du moteur monocylindre expérimental lancé par Bombardier Inc. Les deux phases antérieures concernaient l'étude du moteur et de son banc d'essai ainsi que leur fabrication et leur mise en place. La phase III se rapporte aux travaux devant aboutir à une installation opérationnelle par la caractérisation du moteur et du banc d'essai comme outil hautement précis de recherche et de développement. Le rapport décrit en outre la chaîne de mesure pilotée par ordinateur, le laboratoire d'analyse des carburants et lubrifiants et le banc d'essai du turbocompresseur. Enfin, il donne quelques-uns des résultats des essais de caractérisation et de corrélation avec les moteurs multicylindres.

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SUMMARY

Observed trends in locomotive operation and medium-speed diesel engines in general indicate the need for continuing improvement in both reliability and efficiency. This fact was recognized in the late seventies when Bombardier Inc. began concentrating its efforts on improving the performance characteristics of its 251 engines. In 1981, work commenced on three distinct projects:

1) A study to increase the horsepower output of the 251 engines to 250 hp/cylinder;
2) A study to define the capability of burning off-specification fuels; and
3) The design and development of a new medium-speed engine, the B-2400.

The justification for a single-cylinder engine based on development economics alone was apparent.

After a search for, and assessment of, available research engines, the Bombardier single-cylinder research engine (BSCRE) program was proposed to the Transportation Development Centre in 1981. The proposal outlined the phases leading to an operational BSCRE facility. TDC's co-sponsorship of this program began in 1982. Phase I was documented in the Transport Canada report "Design of a single-cylinder medium-speed research engine and test facility", **TP 4844E** (1983), and Phase II in "Bombardier single-cylinder medium-speed research engine and test facility: Establishment of test facility", **TP 6876E** (1985).

This report covers work done in Phase III, "Qualification". One of the tasks addressed in this phase was the purchase and installation of an independent charge air supply compressor and a computer data acquisition system, thereby completing the required engine supporting equipment.

Engine qualification studies consisted of a series of tests to verify the performance of the various engine components/systems under normal and abnormal operating conditions. Performance maps and power assembly temperatures were taken. In addition, friction horsepower values were measured and compared to the multi-cylinder engines.

The following task, single vs multi-cylinder fuels correlations, consisted of three activities: design and installation of a fuel supply and blending system; building of a fuels and lubricants analysis laboratory; and correlation tests of alternative fuels previously done on a multi-cylinder engine. From the combustion traces, it could be seen that the rate of pressure rise and maximum pressure for the two fuels tests were similar on both engines.

The BSCREs are engine derivatives of turbocharged engine families; to understand the influence of turbocharger characteristics and performance relative to engine performance, a separate test rig is required, since single-cylinder engines cannot support an exhaust driven turbo blower. Within the scope of this phase was the task of designing a test rig and manufacturing some of the major components. Completion of the test rig will be the subject of a subsequent phase. The functional specification calls for three modes of operation. In the open loop mode, air is supplied to the combustor from an external air source and then to the turbine, while the air produced by the turbocharger compressor is exhausted to atmosphere. In closed loop mode, the turbo compressor delivers air to the turbine via the combustor. The mixed mode is a combination of the closed and open loop modes.

The three-modes capability allows data to be acquired from either the turbine or compressor away from their natural match.

It can be concluded that the tasks performed in this phase of the BSCRE program have successfully brought the engines and test facility to operational status.

SOMMAIRE

Les tendances observées montrent que les moteurs diesel semi-rapides, en général, et ceux à usage ferroviaire, en particulier, doivent faire l'objet d'un relèvement constant de leur fiabilité et de leur efficacité. C'est la raison pour laquelle, vers la fin des années 70, Bombardier Inc. a entrepris de relever les performances de son modèle 251. En 1981, trois programmes étaient lancés:

1) étude visant à porter la puissance du moteur 251 à 250 HP par cylindre;
2) étude sur l'aptitude à brûler des carburants hors normes;
3) étude et développement d'un nouveau moteur semi-rapide, le B-2400.

La réalisation d'un monocylindre se justifiait dès lors sur le seul plan économique.

Après avoir fait un tour d'horizon des moteurs expérimentaux sur le marché et les avoir évalués, en 1981, Bombardier propose son projet de moteur monocylindre expérimental au Centre de développement des transports (CDT), proposition dans laquelle étaient décrites les différentes phases devant aboutir à la réalisation de ce moteur et de son banc d'essai. le CDT accepte de coparrainer ce projet en 1982. La phase I des travaux fait l'objet du rapport du CDT, **TP 4844E** (1983), intitulé: "Design of a single-cylinder medium-speed research engine and test facility"; la phase II est décrite dans le rapport **TP 6876E** (1985), intitulé: "Bombardier single-cylinder medium-speed research engine and test facility: Establishment of test facility".

Le présent rapport concerne la phase III traitant de la caractérisation, dont l'un des éléments a été l'acquisition et la mise en place d'un compresseur d'air séparé et d'une chaîne de mesure assistée par ordinateur, tous deux destinés à la recherche.

Les travaux de caractérisation ont comporté une série d'essais visant à vérifier les performances des divers organes ou circuits du moteur, dans des conditions normales et anormales. Les performances ont été cartographiées et les caractéristiques thermiques déterminées. En outre, les pertes de puissance ont été mesurées et comparées à celles des moteurs multicylindres.

La tâche suivante (essais de corrélation entre les carburants pour moteurs mono et multicylindres) a nécessité trois actions, soit: étude et mise en place d'un système d'alimentation et de mélange des carburants; construction d'un laboratoire d'analyse des carburants et lubrifiants; essais de corrélation sur divers carburants de substitution précédemment essayés sur un multicylindre. Les diagrammes de combustion ont montré que la vitesse de montée en pression et les pressions maximales sont identiques dans les deux groupes d'essais.

Le moteur monocylindre expérimental de Bombardier est un dérivé de la famille des moteurs à turbocompresseur; pour comprendre l'influence de la turbocompression sur les performances du monocylindre, il a fallu construire un banc d'essai séparé pour le turbocompresseur, le monocylindre n'ayant pas de place pour une turbine motrice entraînée par l'énergie des gaz d'échappement. Le programme prévoyait l'étude de ce banc d'essai et la fabrication de quelques-uns des principaux organes. Le parachèvement de ce banc d'essai fera l'objet d'une phase ultérieure. Dans la spécification fonctionnelle, trois modes d'alimentation sont prévus: en circuit ouvert, la chambre de combustion alimentée en air par un réservoir séparé alimente à son tour la turbine d'entraînement, tandis que l'air comprimé par le turbocompresseur est rejeté à l'atmosphère; en circuit fermé, le turbocompresseur alimente la turbine via la chambre de combustion; en circuit mixte, qui est une combinaison des deux circuits précédents.

Une telle souplesse permet aux chercheurs d'acquérir des données sur le fonctionnement de la turbine ou du compresseur dans des conditions plus ou moins éloignées des conditions optimales.

Les résultats obtenus sont maintenant tels que le monocylindre et son banc d'essai peuvent être déclarés opérationnels.

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1. INTRODUCTION

Beginning in 1981 a systematic program was initiated by Bombardier to satisfy the need for a "state-of-the-art" medium speed diesel engine research tool. This single-cylinder engine would be representative of the current engines in Canadian railway services.

A program was formulated and proposed to TDC. This proposal was accepted by TDC who awarded a funding support contract to Bombardier in 1982. Since the above date phases 1 and 2 have been completed and documented in reports TP484E and TP6876E.

The modal objective of this program was to develop, through the use of a single-cylinder research engine, locomotive engines which are fuel efficient and capable of burning alternative and off-specification fuels.

This report discusses the third phase of the programme whose objective was to bring the Bombardier single-cylinder research engine (BSCRE) test facility to operational status.

The work performed to achieve this objective consisted of research studies and tests which would establish a baseline for correlation with parent multi-cylinder engines and other BSCRES. The importance of this data base has subsequently been highlighted by the purchase of a 1-251 BSCRE by the American Association of Railroads (AAR) was installed at Southwest Research Institute and the purchase of a 1-B2400 BSCRE by the National Research Council (NRC), Ottawa.

In addition to the above this phase included the installation of a computer data acquisition system, the establishing of a fuels and lubricant analysis laboratory, and the design of a turbocharger test cell. With the two complementary test cells, the BSCRE facility is capable of investigating all aspects of the modern medium speed diesel railroad engine.

2. EQUIPMENT AND INSTALLATION

As stated above the objective of this phase of the program was to bring the BSCRE test facility to operational status. It was necessary, therefore, to purchase and install those items of equipment which were not covered in the previous phase because of a limitation of funds: the computer data acquisition system (C-DAS) and the charge air compressor.

2.1 Charged Air Supply

To this point the BSCRE's received charge air from the plant's main supply and was subject to fluctuations due to shop demand. The compressor selected would satisfy both BSCRE's (1-251 & 1-B2400) and the turbocharger influence and design (TIAD) test cell which, when completed, will also require combustion air. An Ingersol-Rand rotary compressor, model SSR-XF300, water cooled with the inlet capacity of 1420 CFM @ 100 PSIG: and driven by a 300 HP, 460/3/60 motor was installed. Also included in this package was the control panel, shutdown annunciator panel and an enclosure which reduced the noise level to 85 dBA @ one metre. It would seem that this noise level was measured in free field since after complaints from the lab personnel a noise survey showed a level of 95 dBA. This increase in level could be due to the hard highly reflective surfaces of the room. A concrete enclosure has been built around the compressor which will be acoustically treated in stages until an acceptable noise level is reached.

2.2 Computer Data Acquisition System (C.DAS)

A limited amount of data and engine control was manually done prior to the C-DAS installation. This type of engine control was adequate during the shake-down stage but not for precision and accuracy, which is required for research and development.

Three main steps made up the design process of the system, the first was to define the system requirements; such factors as of signal to be measured, number of channels, speed at which data will have to be acquired, and external peripherals for storing and making hard copies of data. Next, the selection of an appropriate micro-computer and compatible data acquisition subsystem. The final step was to choose the micro-computer peripherals i.e. printer, plotter, disk drives, etc.

The C-DAS as configured and installed by Bombardier engine R&D department consists of two (2) sub-systems, the low speed data acquisition (LS-DAS) and the high speed data acquisition (HS-DAS). These systems are described here.

2.2.1 HS-DAS (Ref. Fig. 3, Appendix "A")

The high speed data acquisition system is composed of a number of units and sub-units which when used in conjunction with each other define the physical processes taking place in the combustion chamber of the engine before and after combustion takes place.

The system is composed of the following:

- Sensors and their associated signal conditioners
- A high resolution crankshaft position encoder
- A four (4) channel digital oscilloscope (16K total memory) coupled to a dual floppy disc recorder
- A software engine analysis program (floppy disc) to perform mathematical functions on the stored data
- A digital plotter for hard copies of stored data.

The sensors utilized are for measuring the following parameters:

- Intake port air pressure
- Injection pressure
- Needle lift (time duration)
- Combustion pressure
- Exhaust port pressure

The above mentioned sensors are connected to signal conditioners which feed the conditioned signals to the digital oscilloscope. The high resolution shaft position encoder indicates shaft position as well as providing external trigger and timing pulses to initialize the measuring sequence of the digital oscilloscope. The four channel oscilloscope measures the inputted waveforms, takes the mean average, stores the data in its own memory bank, and, on command, transfers the stored data to one channel of the floppy disc recorder, the stored data can also be transferred back to the memory of the oscilloscope. The engine analysis software package (floppy disc) analyses stored data, computes and displays thermodynamic (P-V) and associated functions. A hard copy of the displayed or stored data is available by means of the digital plotter.

2.2.2 LS-DAS (Ref. Fig. 2, Appendix "A")

The low speed data acquisition system as used in the engine also controls and actuates engine functions.

Engine processes are measured by transducers and are routed to their respective signal conditioners, the resulting conditioned signals and inputed to the Keithley DAS 500 system. The Keithley system, being microprocessor based, is able to communicate with the IBM P.C. computer. Communications between the Keithley 500 system and the IBM computer are based on a memory mapped input-output system, where each command function is mapped to a memory location in the IBM computer memory.

A disc drive located inside the IBM computer contains the software program for data gathering and control functions. By means of a key board, the operator inputs various commands to the computer, which are routed to the respective memory slots as defined by the software program. Completion of the command and computational process, data is displayed on a video monitor for visual observation. Hard copies of the measured data are available from the printer. A sample is given in Appendix "A" Fig. 4.

3. ENGINE BASELINE PERFORMANCE

After the initial running-in of an engine a comprehensive performance map has to be taken before any committment to research and development work. In addition, because of copies of both the engine variants, (1-B2400 and 1-251), being sold and installed at NRC and Southwest Research respectively, the inherent characteristics must be known in order to support and assist these users. It should be noted that the approach to this activity differs for the 1-B2400 and the 1-251 in that the BSCRE of the B2400 preceeded the multi-cylinder engine and would be used to establish start-up parameters. On the other hand the performance characteristics of the 251 are known and the BSCRE must be adjusted to meet those parameters.

Fig. 1 Appendix "E" is a sample report which addresses the 1-B2400 running-in and preliminary tests (baseline). In addition some data is included covering the 1-251 engine. See Fig. 2 Appendix "E".

4. ENGINE QUALIFICATION STUDIES

A series of tests were conducted on both the I-B2400 and 1-251 engines which would demonstrate the performance of these engines as research tools and also prove the supporting systems i.e. instrumentation, control, and data acquisition systems. This statement being the main objective of this task. However, in the case of the 1-B2400 the acquired data was used as initial multicylinder start-up parameters.

4.1 1-B2400 Studies

4.1.1 Cylinder head

Specially prepared cylinder heads with thermocouples, templugs and transducers were fitted to observe the followings:

- Head temperature at various locations
- Heat flux and mean gas temperature
- Coolant flow
- Fire deck fillet stress

The data obtained confirmed the expected cylinder head design, thermal characteristics and qualified the methods and techniques used.

4.1.2 Fuel Injection Equipment (FIE)

The object of this activity was to optimize the FIE for B2400 engines and study the fuel pump drive system dynamics.

Included in the scope were

- The procurement and modification of injector holders, transducers, amplifiers, instrumented injectors and optical encoder.

- Running of engine with FIE component configurations including delivery valve, nozzle angle/hole size/hole number/protrusion/opening pressure, fuel pump element size/timing.

- High speed measurements and engine mapping.

4.1.3 Valve Train

This activity addresses valve train dynamics and temperatures with the objective of establishing the optimum valve train clearance and minimizing dynamic forces.

Strain gauges were fixed to valve train components to record dynamic signals for different cold clearance settings. The valves were drilled and thermocouples inserted and temperatures recorded at different loads. From these tests the maximum exhaust valve temperature is set by the fatigue and corrosion limits which is a function of the material. At the optimized condition specially machined valves were used to observe hardness relaxation and a map of valve temperature change was made. The valve seats were also tested concurrently.

4.1.4 Piston

Three areas of interest in piston development are:

- Piston Crown temperature and related oil flow.
- Piston top liner clearance which is dependent on piston skirt temperature.
- Piston ring pack and liner interface.

The acquisition of actual piston temperatures has always been difficult to measure, and in most cases only an approximation or relative value obtained by a post process such as tem- plugs or hardness relaxation. The swing-link apparatus purchased from AE Engine Components Inc. gives the ability to obtain piston temperatures throughout the operating range. To perform this exercise the crankcase of the 1-B2400 had to be modified to mount the swing-link. (see Fig. 1 Appendix "B") The analysis of rings and cylinder liner interface require precise control and measurement of lube oil con- sumption, for this reason an engine driven lubricating oil source was devised. Also in order to study the effect of piston cooling due to oil flow, an oil cooling jet was fitted into the system.

The results of these studies were used to verify the B2400 piston and ring pack design.

4.1.5 Cylinder Liner Temperature

The objective of this activity is to define the temperature profile at the piston ring reversal area of the cylinder liner under operation throughout the engine load and speed schedule.

A cylinder liner containing twenty-six (26) thermocouples were installed and continuous temperature measurements were taken (See Fig. 5 Appenxix "B").

The data obtained was used to verify liner design, specifically the coolant flow at the upper ring reversal belt.

4.2 1-251 Studies

As stated earlier, since the basic objective of the studies on this engine is to duplicate performance characteristics of the parent multi-cylinder engine, the baseline segment of this project covered most of this work. However two areas of interest centred around the new cylinder head and deep bowl piston. Therefore the following two activities were planned in order to study the performance impact and limits due to these components.

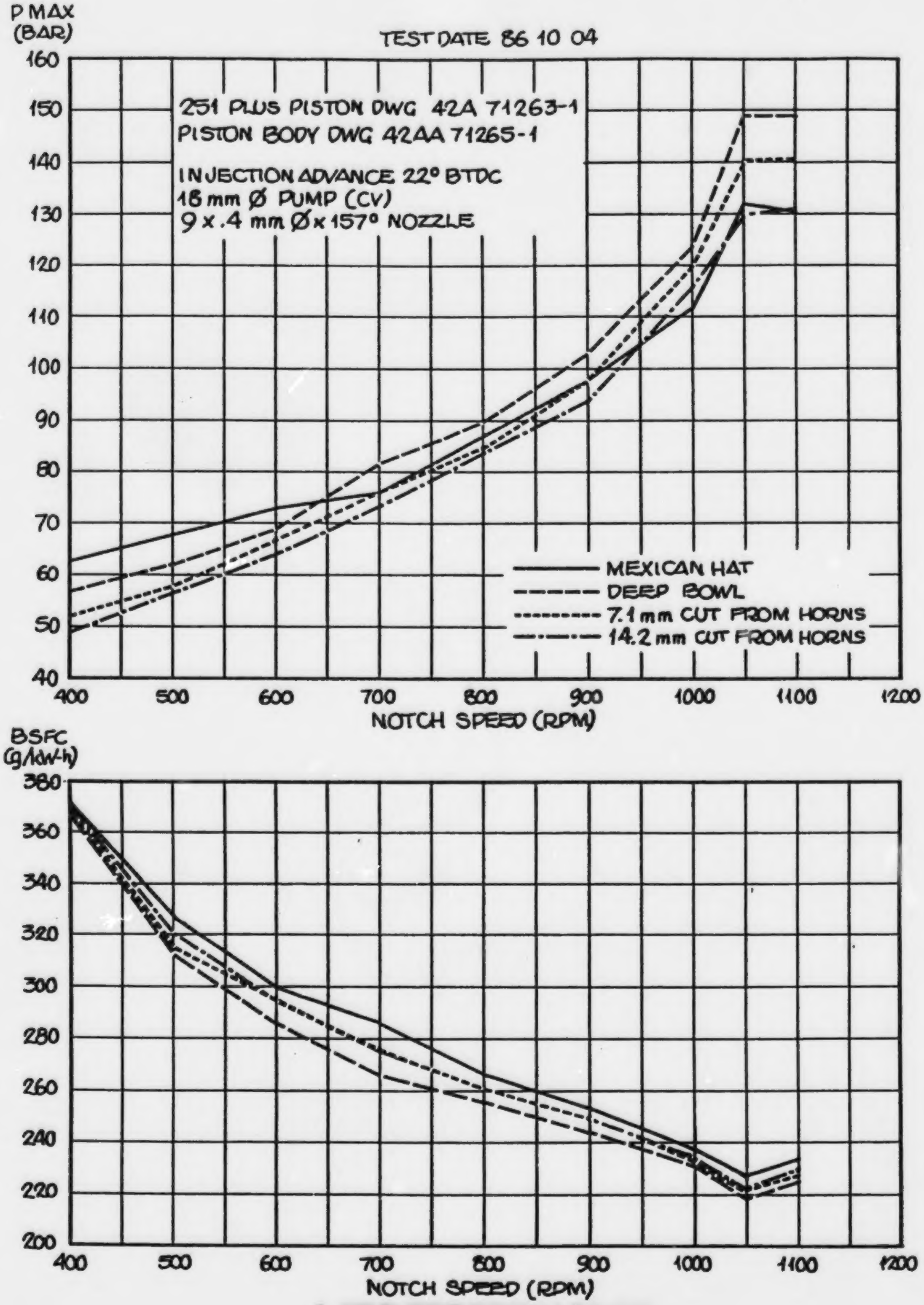
4.2.1 New Cylinder Head

This cylinder head was designed to have superior cooling over the current production head and also better thermal shock resistance due to material and sructure. The temperature assessment work done here is as outlined in 4.1.1 except for the different head.

Thermal shock resistance was measured comparatively by allowing the engine (head) to reach maximum operating temperature, draining the head of coolant and the pumping fo cold water into the head. This cyclic heating and cooling is continued until a crack occurs. The number of cycles are compared to other cylinder heads of different design and/or material.

4.2.2 Combustion Optimization (Performance)

The principal reason for this work was to compare the performance of various piston bowl configurations with related fuel injection characteristics, therefore optimizing combustion. The tests consisted of operating the engine with current production equipment at maximum cylinder and injection pressures then installing new deep bowl pistons with various compression heights (geometric compression ratios) and injection nozzle timing/angle/hole size/protrusion and pressures, comparing PMAX and BSFC. (See Fig. 4.1)



TEST DATE 86 10 04

251 PLUS PISTON DWG 42A 71263-1
PISTON BODY DWG 42AA 71265-1

INJECTION ADVANCE 22° BTDC
18 mm Ø PUMP (CV)
9 x .4 mm Ø x 157° NOZZLE

1-251 PERFORMANCE
PISTON BOWL INFLUENCE

FIGURE 4.1

5. ENGINE CORRELATION (Single vs multi-cylinder)

This task brings the single-cylinder engine test facility to the status at which it meets the modal objective of the BSCRE programme. That is, "The capa- bility of burning alternative and off-specification fuels." In order to perform this function, three activities were required.

- The design and installation of a fuel supply and blending system, including instrumentation.
- The building of a fuels and lubricants analysis laboratory.
- Correlation tests of alternative fuels previously run on a multi-cylinder engine under a DND contract # 2SV84-00256.

5.1 Fuel Supply and Blending System

Heavy fuel oil (HFO) (700 Cst.) and diesel fuel N° 2 (DF2) stored in two 9090L (2000 gal.) tanks installed outside and surrounded by a concrete dike. The HFO tank is insulated and fitted with electric heaters. Portions of these oils are transfered to day tanks located indoors. These tanks have a capacity of 1136L (250 gal.). From the day tanks in response to the viscosity controller, measured quantities of HFO and DF2 pass through a mixer to a heat exchanger and then to the viscometer for verification. Should the viscosity not be as specified, it can be recycled. If the specification is met, the mixture goes to the engine supply tank. (See Appendix "C" Fig.'s 2, 3 & 4.)

5.2 Fuels and Lubricants Analysis Laboratory

The F/L lab. was planned to supplement the development of mechanical test capabilities of the BSCRE. The significance of physical tests on engine components are validated by chemical analysis and is an extremely valuable tool in attempting to predict the compatibility or how a specific lubricant and/or fuel will perform in service operations.

New formulation technologies for petroleum products necessitate a constant review of quality assessment of both new and used lubricating oils and fuels.

The functional specification of the lab addressed the three categories of determining characteristics and compositions fluids, namely:

> Physical tests - Viscosity, flash point, specific gravity, color and appearance which define the nature of the product by measuring physical properties.
>
> Chemical tests - These tests define the composition by determining the presence of elements such as sulphur phosphorus and metals which, as in oils relate to the additive content.
>
> Physico-chemical tests - In this classification are those tests which determine the presence of elements using instrumented physical procedures; those which give information on molecular structure or PH, acidity, and alkalinity values. Physico-chemical tests are generally used to define products for specific applications and the suitability of used lubricants for further service. [1] *

Table 5.1 shows the initial ASTM tests which can be performed. Also a copy of Bombardier's lube oil and fuel maintenance instruction. Appendix "C" Figures 6&7 indicates the requirements, typical of railway lubricating engine oils.

* [] Numbers in parentheses designate references at end of report.

TABLE 5.1 ASTM TESTS

Descriptions	Test Method
Distillation	ASTM D 86
Gravity (API)	ASTM D 1298
Flash point	ASTM D 56/92
Cloud point	ASTM D 2500
Water & sediment	ASTM D 1796
Ash (used oils)	ASTM D 482
Kinematic viscosity	ASTM D 445
Pour point	ASTM D 97
Carbon Residue	ASTM D 524
Total Base number	ASTM D 664
Cetane Index	ASTM D 976
Insoluables	ASTM D 893
Sulphur	ASTM D 1552

5.3 Correlation Tests and Analysis

To perform this work, the 1-251 engine was reconfigured to represent the 12 cyl. 251 which was used as the test engine during the "Alternative fuels for medium speed diesel engine" project for the Department of National Defence [2] [3]. The objective of that project was to identify performance and operational problems which may arise in the future as the quality of fuels used in medium speed diesel engines deteriorates, and the supply of conventional fuels become increasingly varied.

Six (6) non-conventional fuels were tested in the "DND" program. No. 2D diesel, was used as the reference fuel. Basic performance data was taken and compared to the data of reference fuel. See figures 5.1 to 5.7.

A conclusion given in the referenced DND report of major importance to the engine correlation activity was the need for extended engine tests. Considerable savings would be realized in time and money if fuel studies were carried out on the BSCRE. Approximately $230,000. on a 500 hour test would be saved. The fuel selected for this test was the "NRC 1990 diesel fuel" which is a blend of 78% of a distillate cut from 50/50 mixture of conventional western canadian and tar sands crude and 28% of hydrogen treated cracked stock. This fuel contained a substantial level of aromatics and cracked components and is expected to be typical of the diesel fuel quality predicted for the near future.

The procedure followed was similar to the "DND" program, first run engine with the reference fuel no. 2-D, then on NRC-1990 and repeat on the no. 2-D for verification that the engines fixed parameters were unchanged. Figures 5.8 to 5.12 are performance curves taken during the test. A comparison of figures 5.8 and 5.12 show the relationship of the 1-251 and the 12-251. Conclusions drawn from this data indicate the difference in engine set-up of the single cylinder necessary to predict multi-cylinder performance.

FIGURE 5.1

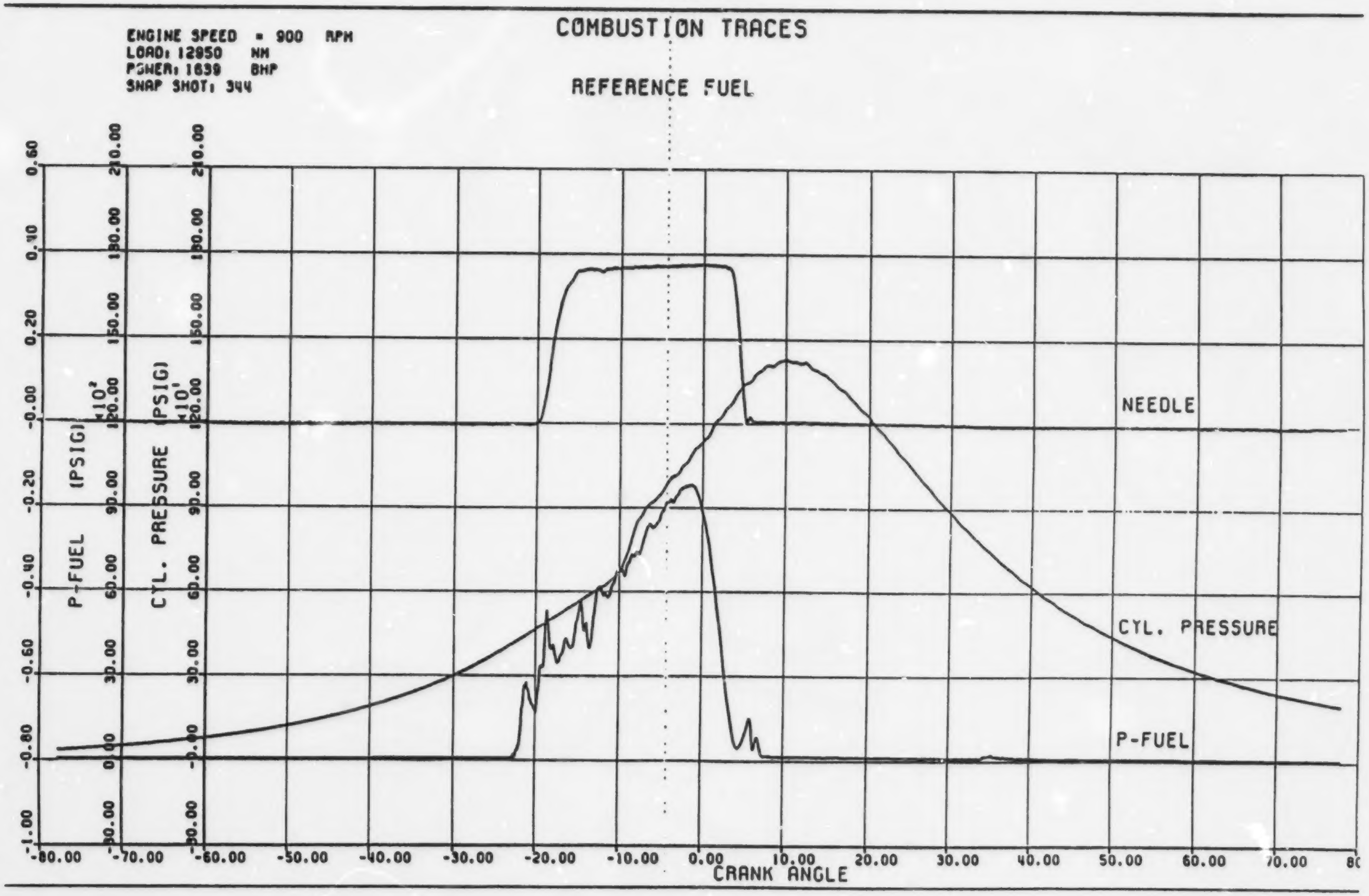
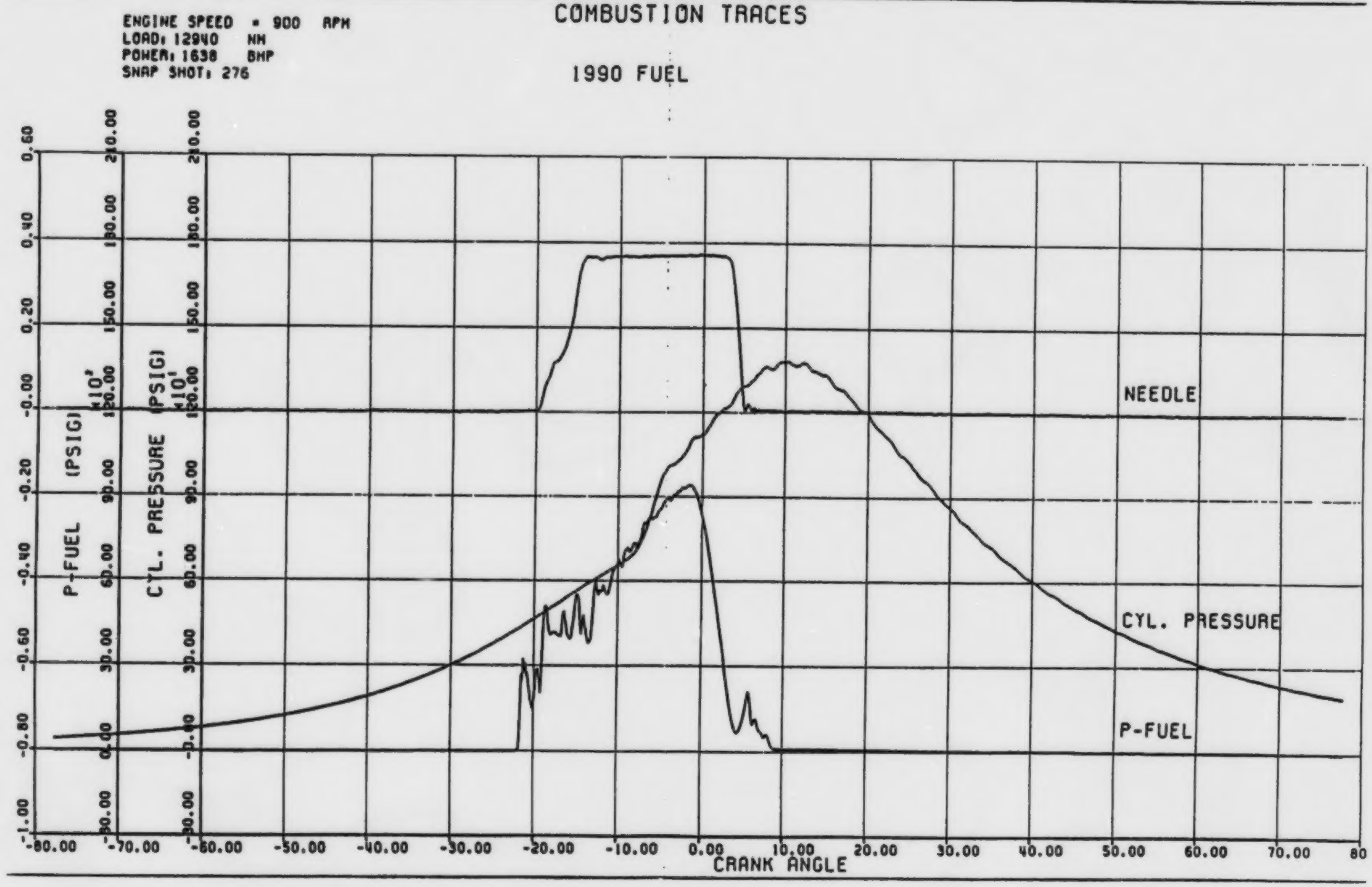

COMBUSTION TRACES
REFERENCE FUEL
ENGINE SPEED = 900 RPM
LOAD: 12850 NM
POWER: 1639 BHP
SNAP SHOT: 344
NEEDLE
CYL. PRESSURE
P-FUEL
P-FUEL (PSIG) ×10²
CYL. PRESSURE (PSIG) ×10¹
0.60
0.40
0.20
-0.00
-0.20
-0.40
-0.60
-0.80
-1.00
210.00
180.00
150.00
120.00
90.00
60.00
30.00
0.00
-30.00
210.00
180.00
150.00
120.00
90.00
60.00
30.00
-0.00
-30.00
-80.00
-70.00
-60.00
-50.00
-40.00
-30.00
-20.00
-10.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80
CRANK ANGLE

FIGURE 5.2


COMBUSTION TRACES
1990 FUEL
ENGINE SPEED = 900 RPM
LOAD: 12940 NM
POWER: 1638 BHP
SNAP SHOT: 276
P-FUEL (PSIG) ×10²
CYL. PRESSURE (PSIG) ×10¹
0.60
0.40
0.20
-0.00
-0.20
-0.40
-0.60
-0.80
-1.00
210.00
180.00
150.00
120.00
90.00
60.00
30.00
0.00
-30.00
NEEDLE
CYL. PRESSURE
P-FUEL
-80.00
-70.00
-60.00
-50.00
-40.00
-30.00
-20.00
-10.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80
CRANK ANGLE

BOMBARDIER INC.

TEST DATE: ENG. HOURS: BUILD NO.: 82.12.16
ENG. TYPE: 12V251 FUEL PUMP: 18 MM NOZZLES: .400 MM 9 HOLES
SIT: 18.0 BTDC TURBO: 165 NOZZLE RING: 18.6 DIFFUSER: 10.7

NOTES:

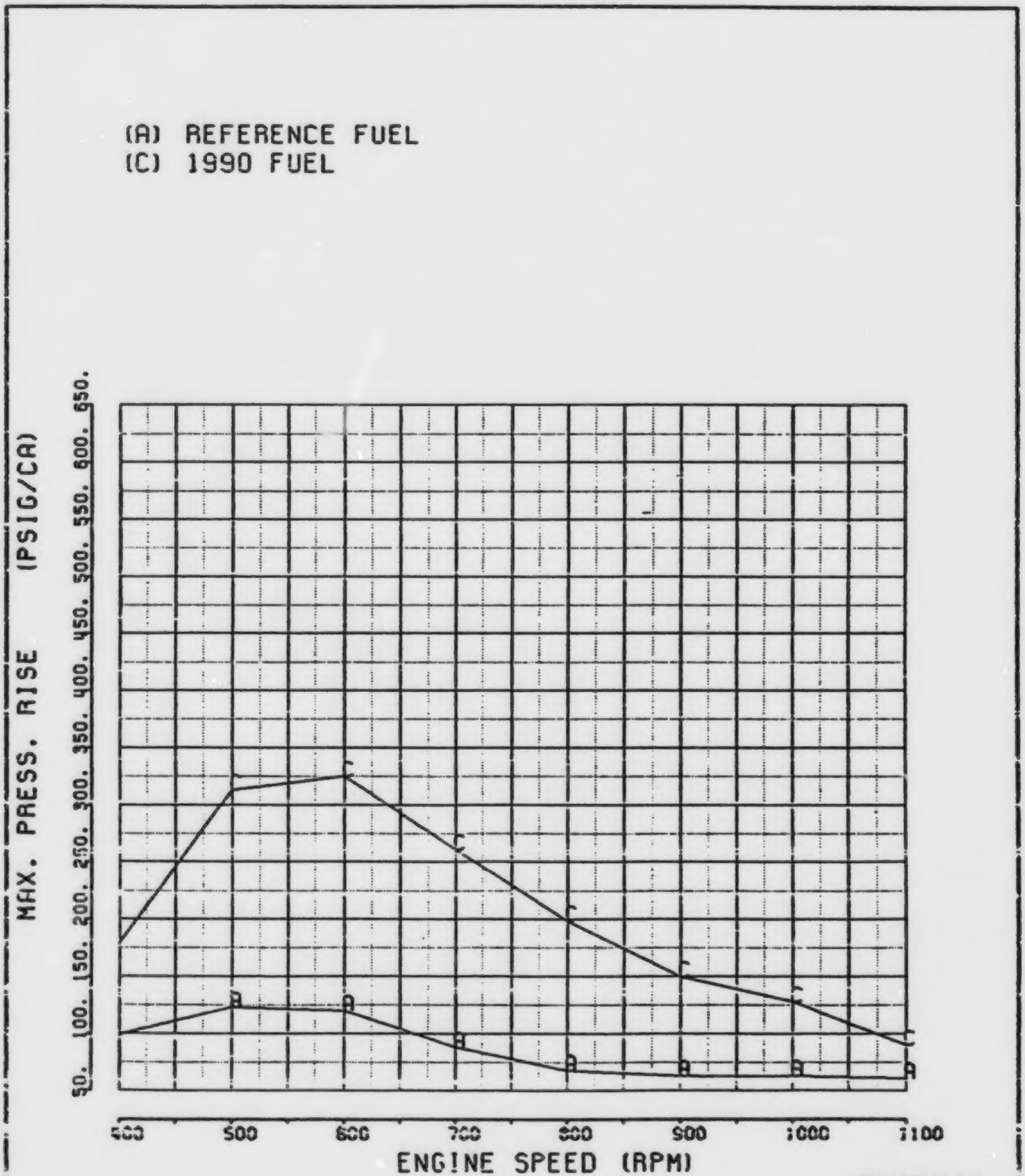


FIGURE 5.3

BOMBARDIER INC.

TEST DATE: ENG. HOURS: BUILD NO.: 82.12.1

ENG. TYPE: 12V251 FUEL PUMP: 18 MM NOZZLES: .400 MM 9 HOLES

SIT: 18.0 BTDC TURBO: 165 NOZZLE RING: 18.6 DIFFUSER: 10.7

NOTES:

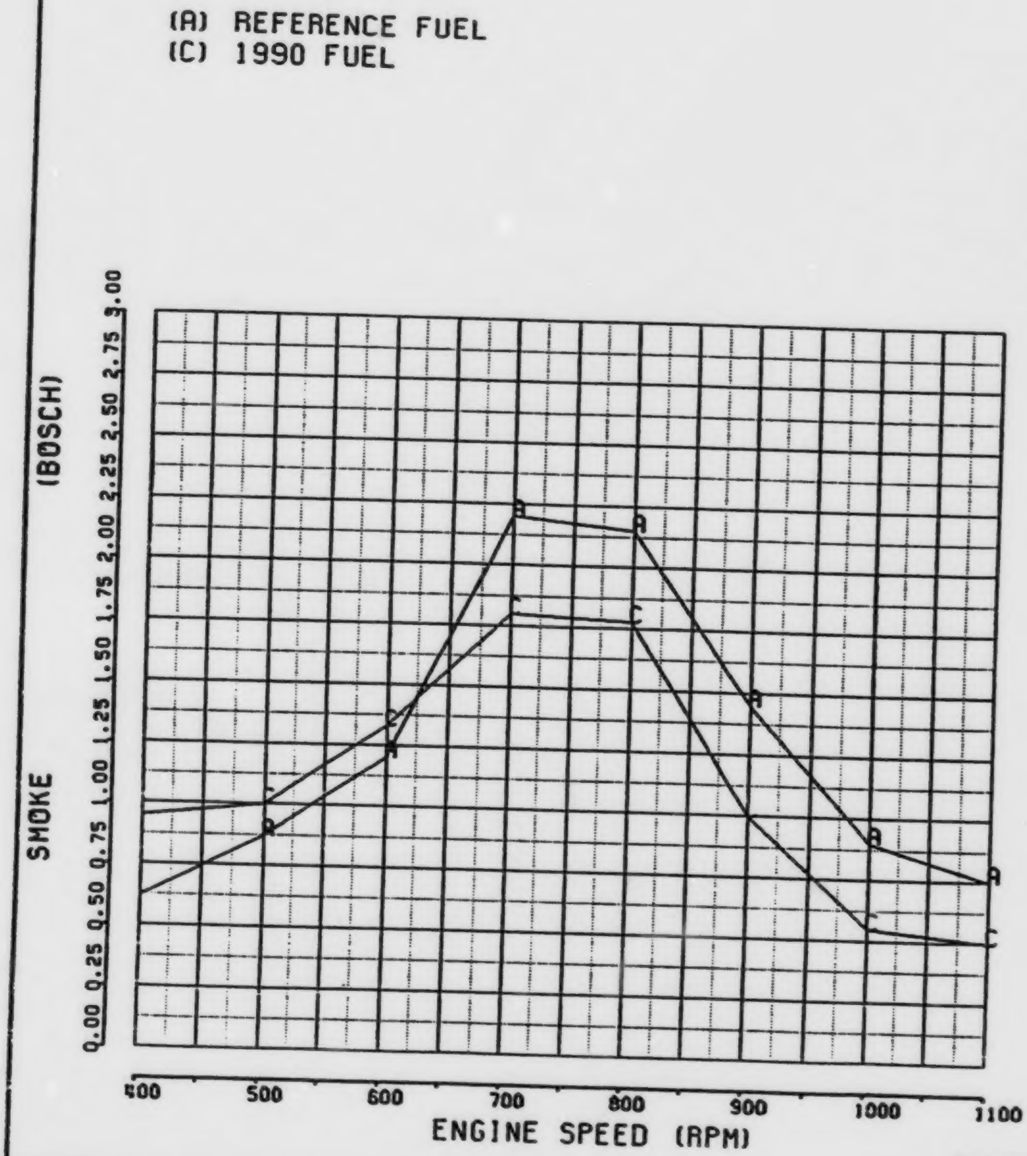


FIGURE 5.4

BOMBARDIER INC.

TEST DATE: ENG. HOURS: BUILD NO.: 82.12.16

ENG. TYPE: 12V251 FUEL PUMP: 18 MM NOZZLES: .400 MM 9 HOLES

SIT: 18.0 BTDC TURBO: 165 NOZZLE RING: 18.6 DIFFUSER: 10.7

NOTES:

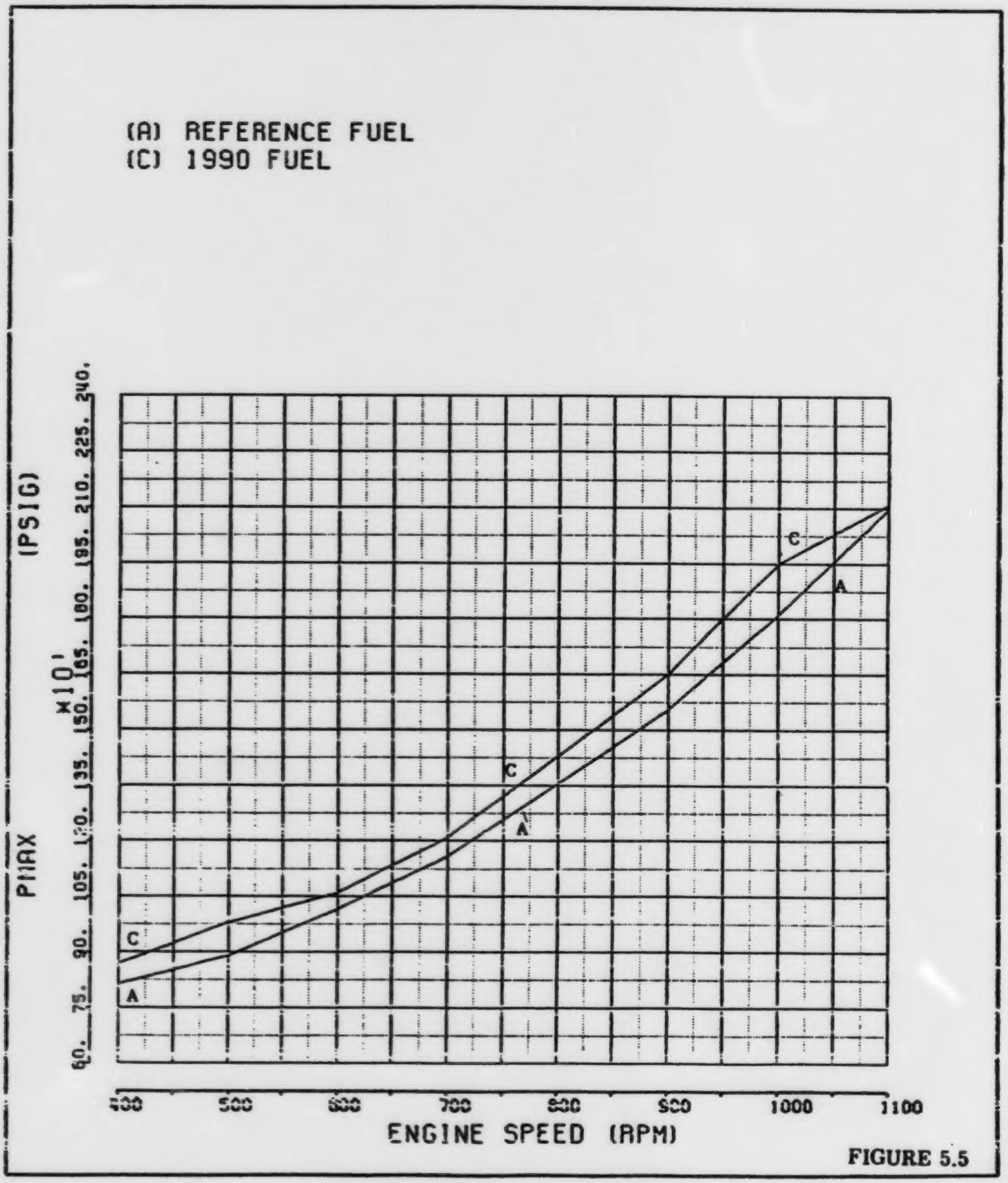


FIGURE 5.5

BOMBARDIER INC.

TEST DATE: ENG. HOURS: BUILD NO.: 82.12.16
ENG. TYPE: 12V251 FUEL PUMP: 18 MM NOZZLES: .400 MM 9 HOLES
SIT: 18.0 BTDC TURBO: 165 NOZZLE RING: 18.6 DIFFUSER: 10.7
NOTES:

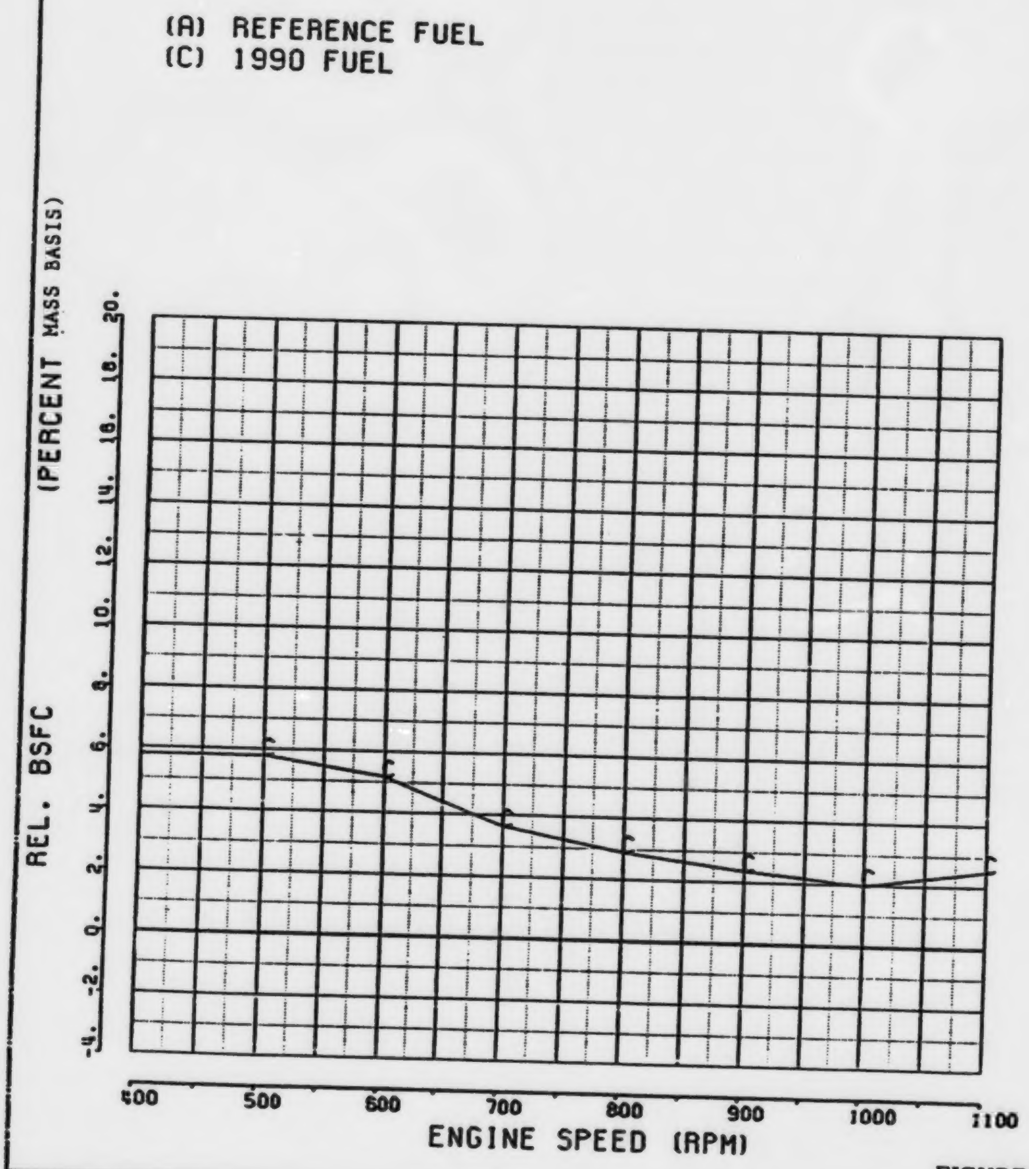
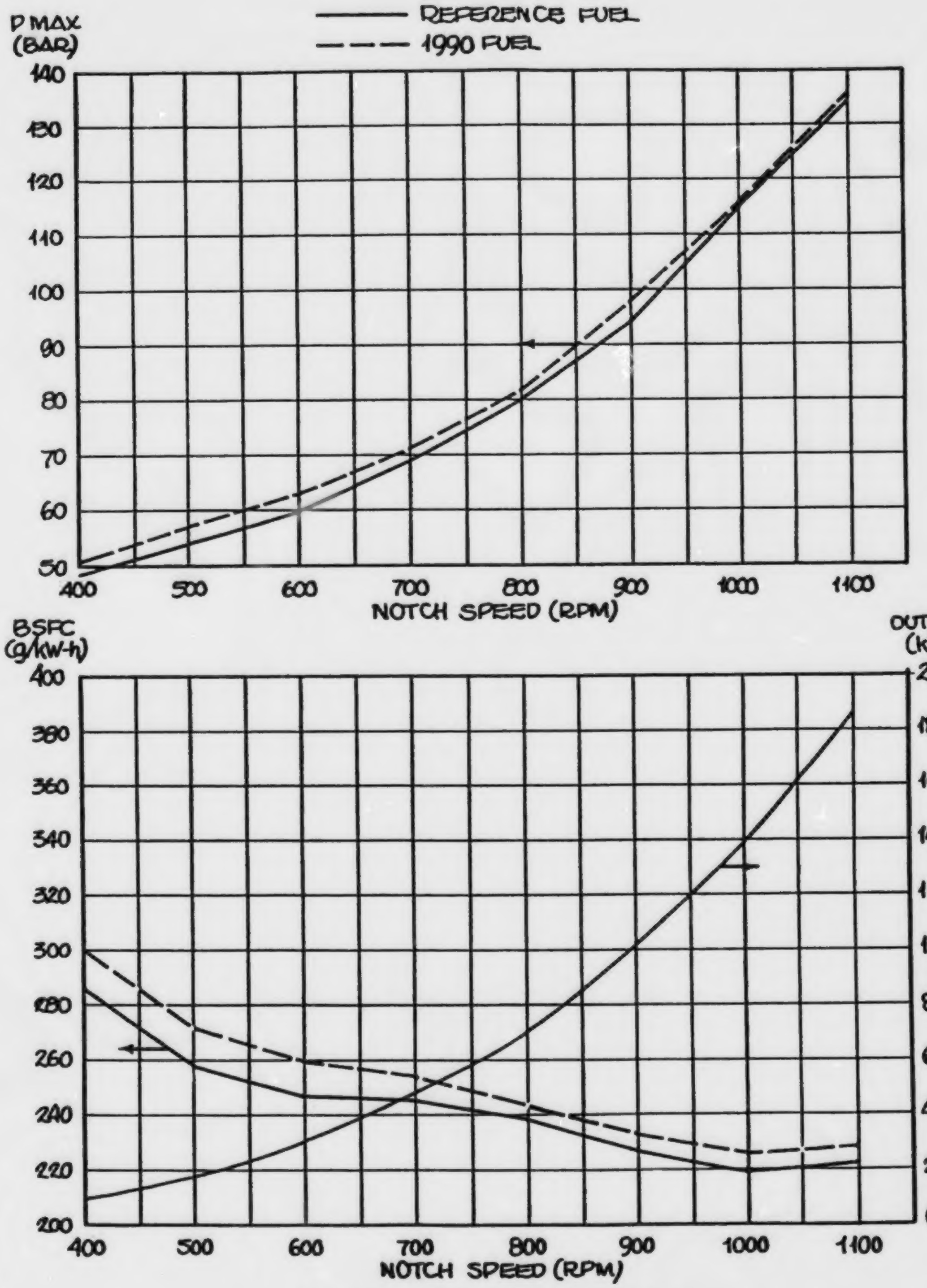


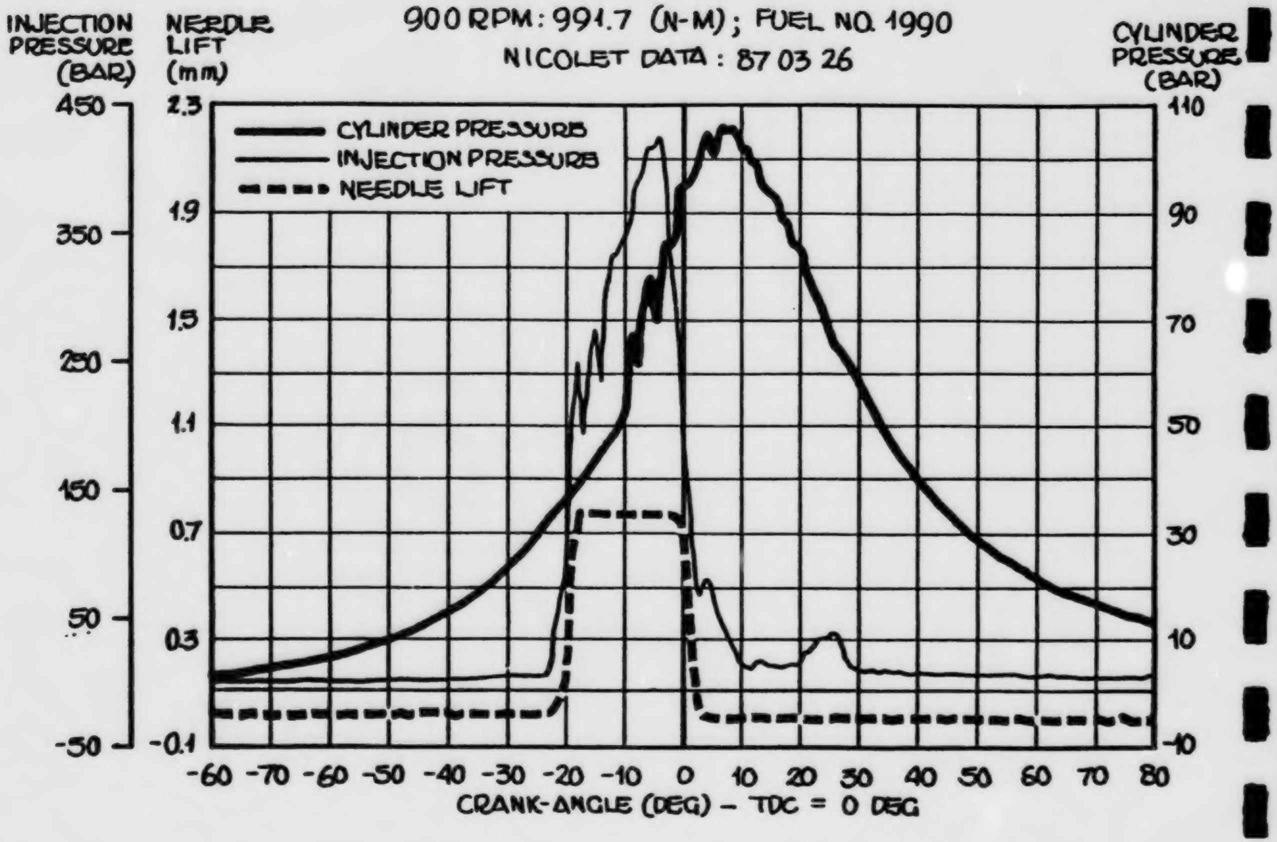
FIGURE 5.6



TEST DATE 84 11 21

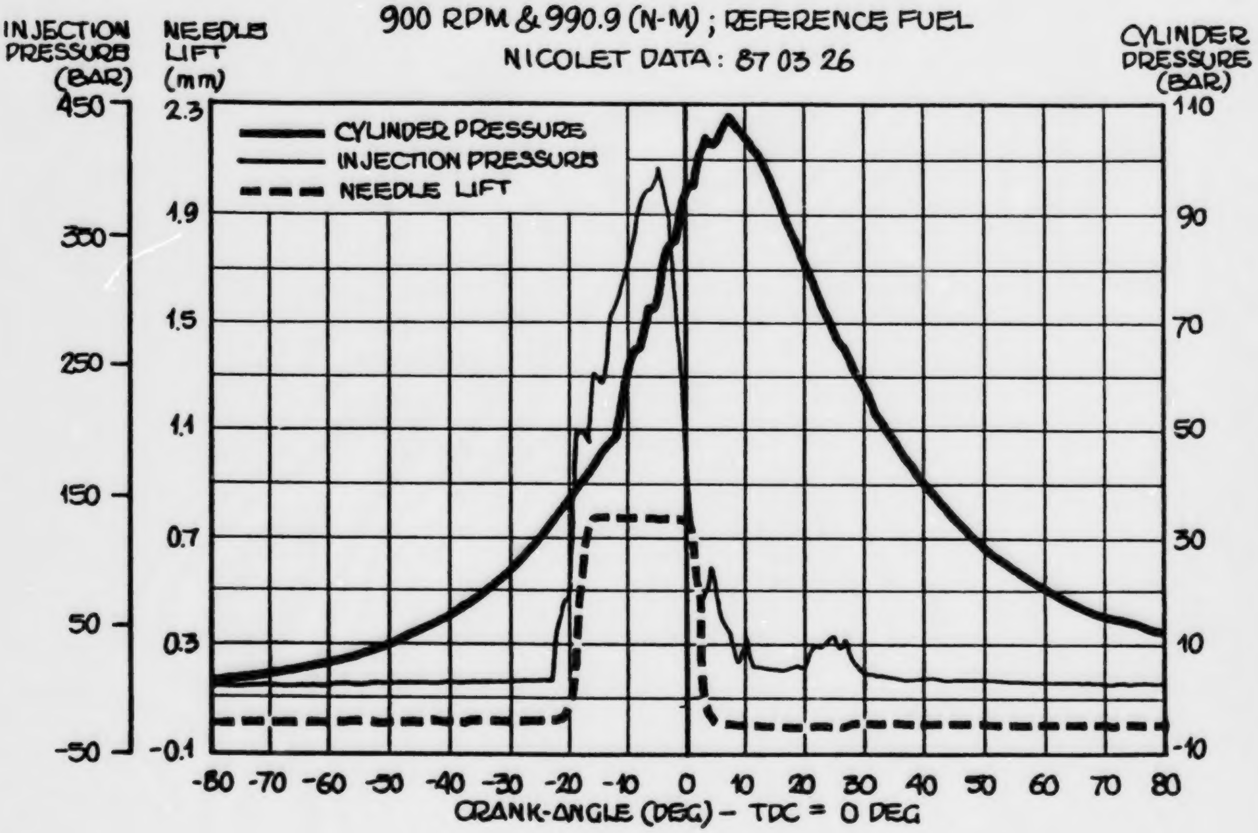
**12-251 PERFORMANCE
FUEL CORRELATION TEST**

FIGURE 5.7



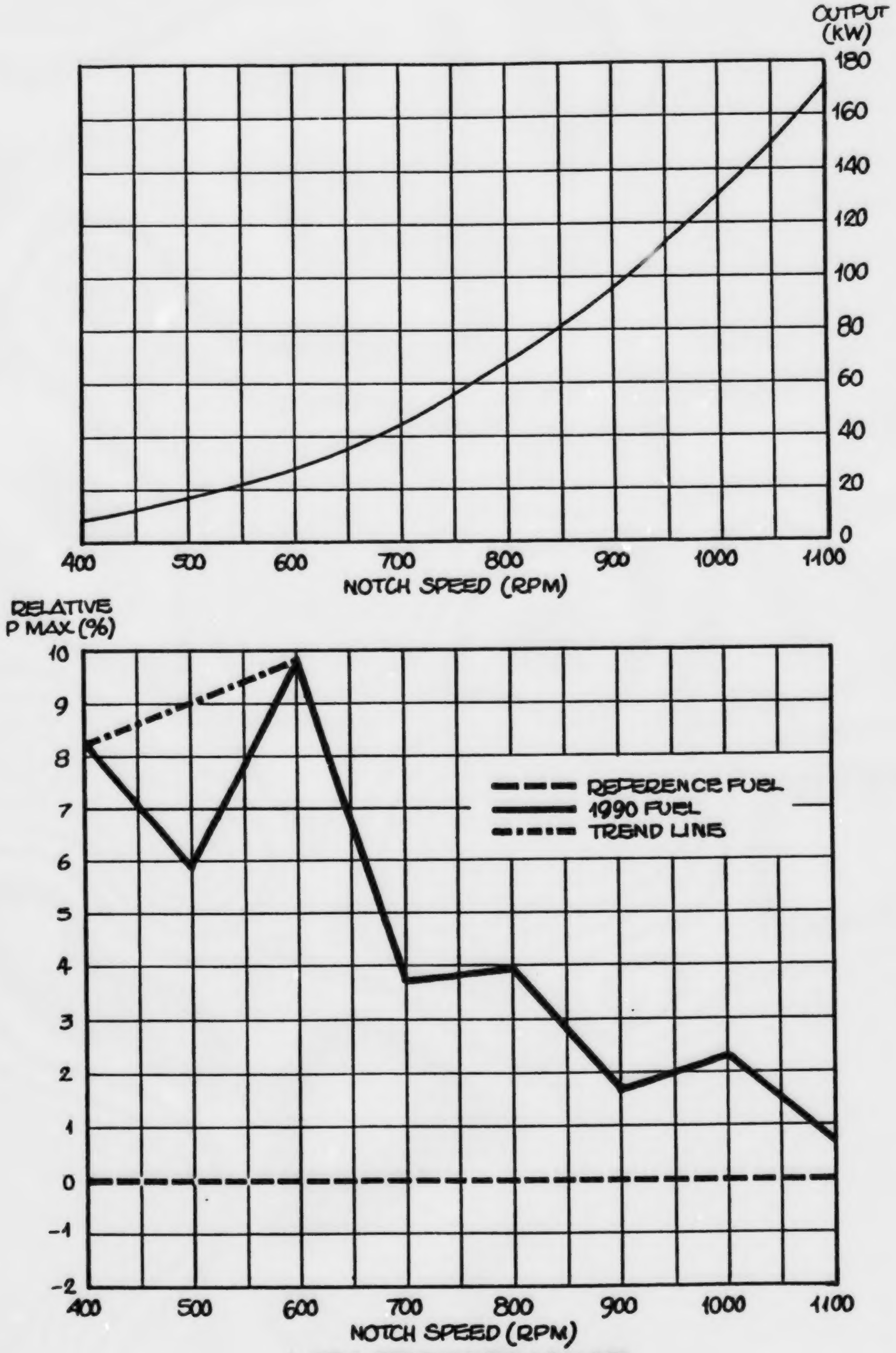
FUEL CORRELATION; 1-251 ENGINE

FIGURE 58



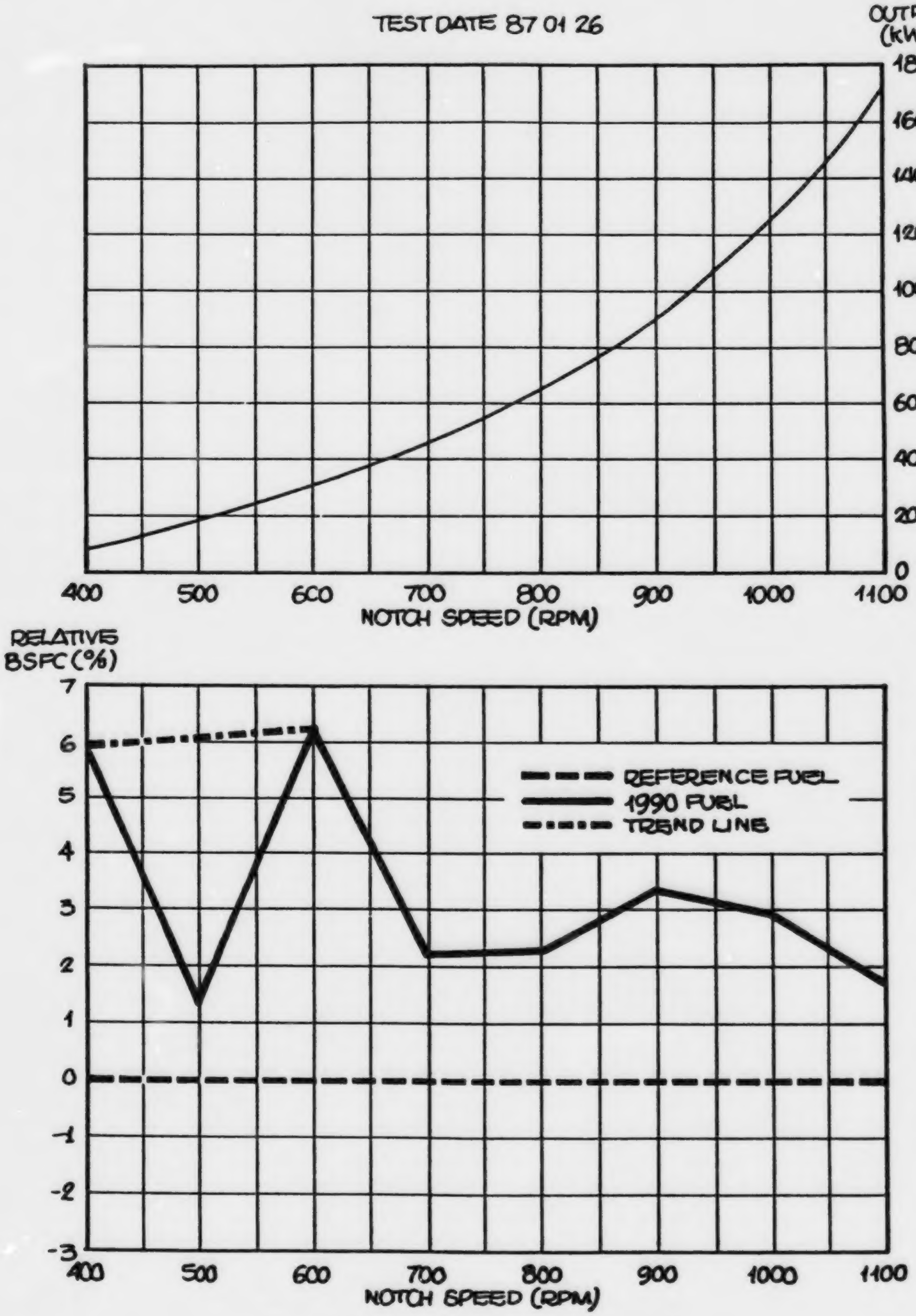
FUEL CORRELATION; 1-251 ENGINE

FIGURE 5.9



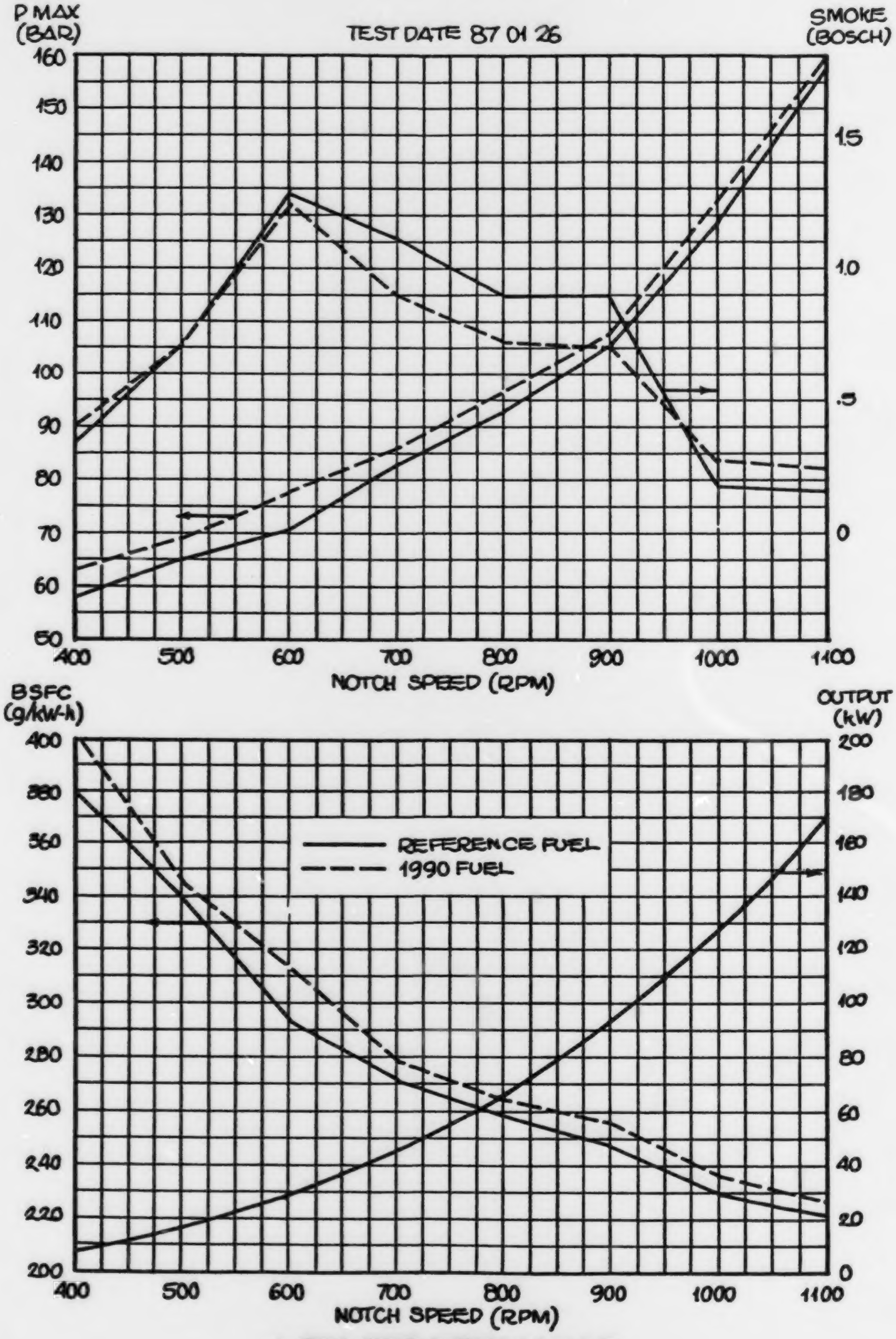
1-251 PERFORMANCE FUEL CORRELATION

FIGURE 5.10



1-251 PERFORMANCE
FUEL CORRELATION TEST

FIGURE 5.11



1-251 PERFORMANCE
FUEL CORRELATION TEST

FIGURE 5.12

6. TURBOCHARGER INFLUENCE TEST CELL DESIGN

The BSCRE in any of its design variants offers the development capability of engine components and in-cylinder process analysis. Both the 251 and B-2400 engine families are turbocharged, therefore the need for understanding the influence and performance of the Bombardier turbochargers is of great importance. Also it is necessary that as the performance and efficiency of the engine advances so must the turbocharger.

A single cylinder engine cannot sustain a turbocharger, consequently a turbo rig is required as a parallel and complementary development tool.

Within the scope of this phase III work was the first stage in establishing the test rig and cell, consisting of producing construction drawings and layouts (see Appendix "D") of the test cell and turbo-rig including control systems. The completing stage and commissioning will be covered under phase IV of the BSCRE program.

6.1 Design Specification

The test rig will be used for turbocharger component developments. Tests will include single stage turbines, compressors as well as scaled models of both. The test rig can also be used for commissioning of complete units.

6.2 General Features

The test rig has the capability to operate in three different modes. The open loop mode where air is supplied to the combustor from an external air source and then supplied to the turbine while the air produced by the turbocharger compressor is exhausted to a dump room or to the atmosphere. The closed loop mode where the turbocharger compressor delivers air to the turbine via the combustor. The mixed mode where air from both compressor and external air supply is fed to the turbine via the combustor.

The three mode capability provide us with the most eco-nomical way to acquire sufficient data from either turbine or compressor away from their natural match. It also provides flexibility to cover a wide range of power.

The test rig will be able to deploy a high level of instrumentation to acquire aerodynamic, thermal and mechanical parameters automatically with in-line data reduction and analysis.

6.3 Test Rig Capacity

Mass flow rates:

1 to 3 lbs/sec. (0.454 Kg/sec. to 1,36 Kg/sec) for the open loop

3 to 17 lbs/sec.(1.36 Kg/sec. to 7.71 Kg/sec.) for the mixed and closed loop

Turbine inlet temperature 100°F (37.8°C) Nominal 1350°F (732°C) max.

Turbine inlet pressure 45 psia (310 KPa) Nominal 65 psia (448 KPa) max.

6.4 Main Components and Circuitry

A. Turbocharger test stand (Skid)

B. Combustor

C. Air circuit

D. Gas circuit

E. Fuel circuit

F. Lube oil circuit

G. Cooling water circuit

H. Controls & instrumentations

6.5 Detail Requirements

6.5.1 Turbocharger Test Stand (Skid)

The turbocharger skid will be of structural steel. With the turbocharger oil sump integrated into the structure.

The height of the skid will be that work on the turbocharger can be performed from the ground level. Options to mount the turbocharger on the skid other than the currently used position will be possible.

- Turbocharger minimum weight is 1800 lb (818Kg)
- Minimum volume of oil sump is 3 cuft. (0.254 m^3) (depending on oil piping).

6.5.2 Combustor

The combustor when installed will be able to operate effectively over the ranges indicated below:

Air mass flow, from 1 to 17 lb/sec. (0.454 Kg/sec to 7.71 Kg/sec.)

Pressure up to 65. psia (448.0 KPa).

Pressure drop should not exceed 5%

Gas temperature 1100°F (593°C) Nominal and 1350°F (732°C) max.

Capable of burning diesel fuels (including heavy fuels).

A provision is being made for cold start up and operation with air mass-flow as low as 1 lb/sec. (0.454 Kg/sec) @ 100°F (37.8°C).

6.5.3 Air circuit

The turbocharger compressor discharge pipe (from compressor discharge to combustor inlet flange) is made of standard steel pipe 10" (25.4 cm) nominal pipe. The recommended minimum distance between the compressed air pipe flange and compressor discharge flange is 40" (101.6 cm). This distance will be used for transient pipes depending on the turbocharger being tested. A gate type control valve installed on the com- pressed air pipe, will be motorized and the speed at which the valve gate closes should not exceed $^1/_4$" (0.64 cm) per second. The motor will be operated by a dead-man electrical switch located inside the operator's control room.

Provision to monitor the position of the gate within its housing for the purpose of comparative testing is alloted for.This may be achieved by attaching the valve spindle to an external indicator visible from the operator's control room window.

The two-way valve will be used to direct the compressed air to either the combustor,ambient or divide the flow between both. The installed valve will be at a convenient location between the combustor and the dump pipe, and as far away from the compressor discharge control valve as practically possible. The diameter of the dump pipe is the same as the compressed air pipe.

The make-up air pipe is connected to the main pipe at a location not less than 6 ft. (1.8 m) from the combustor flange. An expansion joint of appropriate length is installed between the main pipe and the combustor flange. All com- pressed air pipes are insulated to a surface temperature of maximum 80F (26.7°C) assuming a compressed air temperature of 350F (177°C).

The inlet pipe to the compressor will have a minimum straight length, and the diameter depen-ding on the type of turbocharger being tested. For that reason a distance of 8 ft. (2.44 m) is left between the location of the turbocharger inlet and the main inlet pipe. This space will be used to install the various pipes depending on the turbocharger configuration. The air fil- ter used in this system should have a maximum air flow of 17 lb/sec (7.7 Kg/sec.).

The design of the air circuit is such that the total pressure drop (loss) at the entry of the compressor should not exceed 15 ins. (38 cm) of water. Also total pressure drop from the compressor discharge to the inlet of the combustor in the closed loop mode should not exceed 6% of compressor discharge.

6.5.4 Exhaust gas circuit

The combustor exhaust gas pipe is made of 10"ID (25.4 cm) stainless steel tubing. A minimum of 5 ft. (1.5 m) between the end flange of this pipe the location of the gas inlet casing flangest will be used to install the appropriate adaptors to fit the gas inlet of the turbocharger being tested. The length of the pipe is not less than 3 ft (0.914 m).

An expansion joint is installed between the pipe and the combustor flange. This expansion joint will be able to take the thermal growth of all hot pipes; from the turbine gas casing to the combustor flange.

The turbine exhaust pipe discharges exhaust gases to atmosphere. The pipe diameter shall not be less than 10" ID. A transition piece between the turbocharger exhaust gas discharge and the flange of this pipe should be as smooth as practically possible. The rectangular shape of the turbocharger discharge should be maintained to minimum of 5 ft. before the start of the transtion.

6.5.5 Fuel circuit

The flow of fuel oil will be at the rate of 795.0 lb/hr (361 Kg/hr)at maximum operating condition of the test rig. The size of the fuel day tank is 250 gallons (1136L). Fuel pumps and filters are sized to handle the maximum fuel consumption rate.

6.5.6 Lube oil circuit

Lube oil data:

- -Oil flow rate 6 to 7 GPM (27.3 to 31.8L) nominal.
- -10 GPM (37.9L/min) max.
- -Oil pressure 40 to 50 psi (276 KPa to 345 KPa) nominal
- -50 PSI (345 KPa) max.
- -Type of oil SAE40 or other engine oil.

A provision is made to change the inlet oil temperature (not by flow restriction) from 120°F to 190°F (49°C to 88°C) .

Maximum outlet temperature is limited to 230°F (110°C).

6.5.7 Cooling water circuit

There is sufficient water for cooling the main casing and occasionally a water cooled gas inlet casing. The required total water flow required for cooling at maximum operation and, assuming a water cooled gas inlet casing, will be 110 GPM (500L/min). This water will supplied at 170°F (77°C) and 40 to 45 psi (276 KPa to 310 KPa).

REFERENCES

1. Redwood Petroleum and Petrochemical Guide to Quality Railway Products SGS, Supervisor Services.

2. Bombardier Rail and Diesel Products Division. Alternative Fuels for Medium Speed Diesel Engines, Phase I. Report ERD/18/84.

3. Bombardier Rail and Diesel Products Division. Alternative Fuels for Medium Speed Diesel Engines, Phase II. Report ERD/08/85.

APPENDIX "A"

COMPUTER DATA ACQUISITION SYSTEM

Fig. 1 Computer data acquisition system

Fig. 2 Low speed system schematic

Fig. 3 High speed system schematic

Fig. 4 Sample data print-out

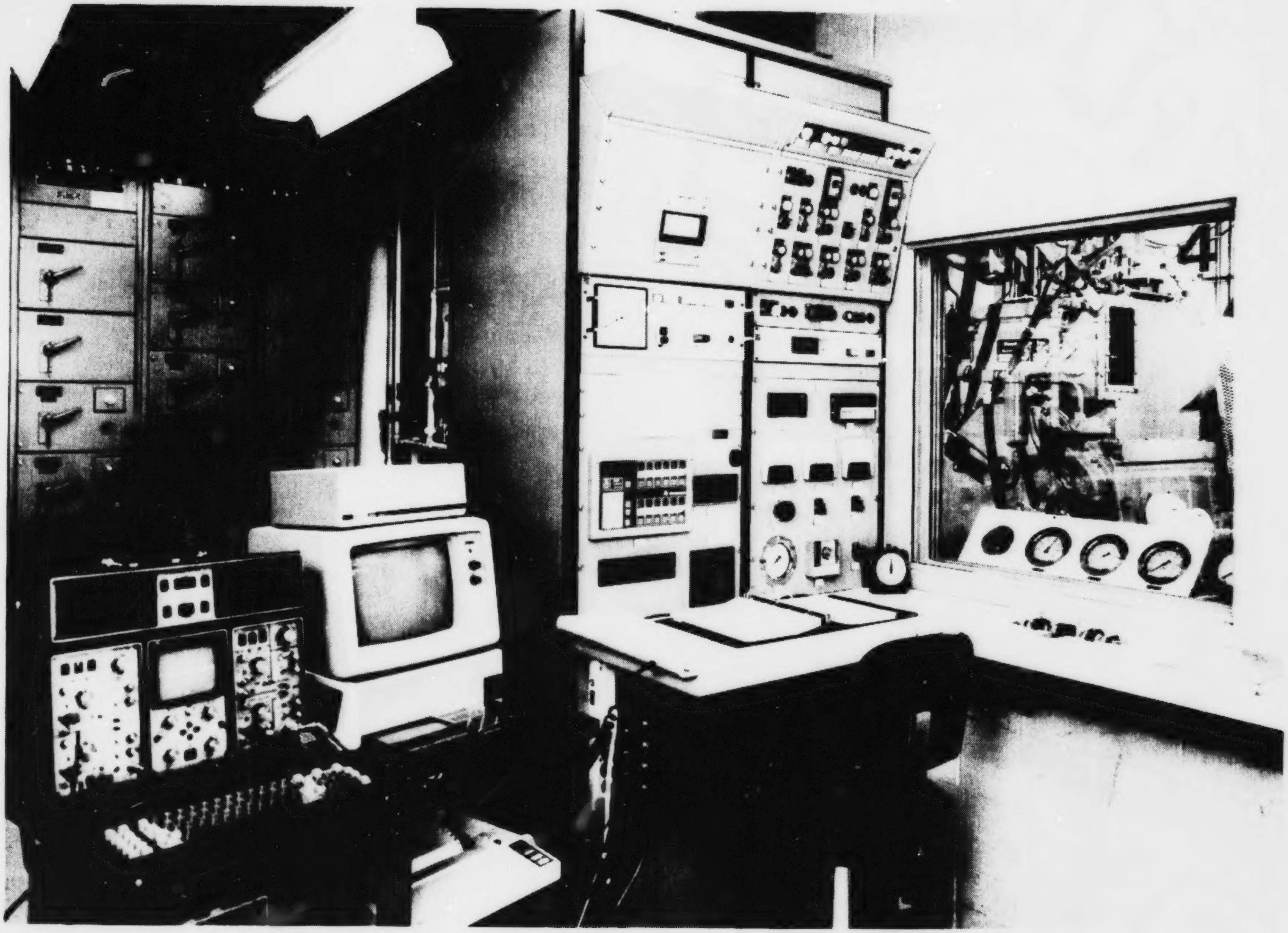
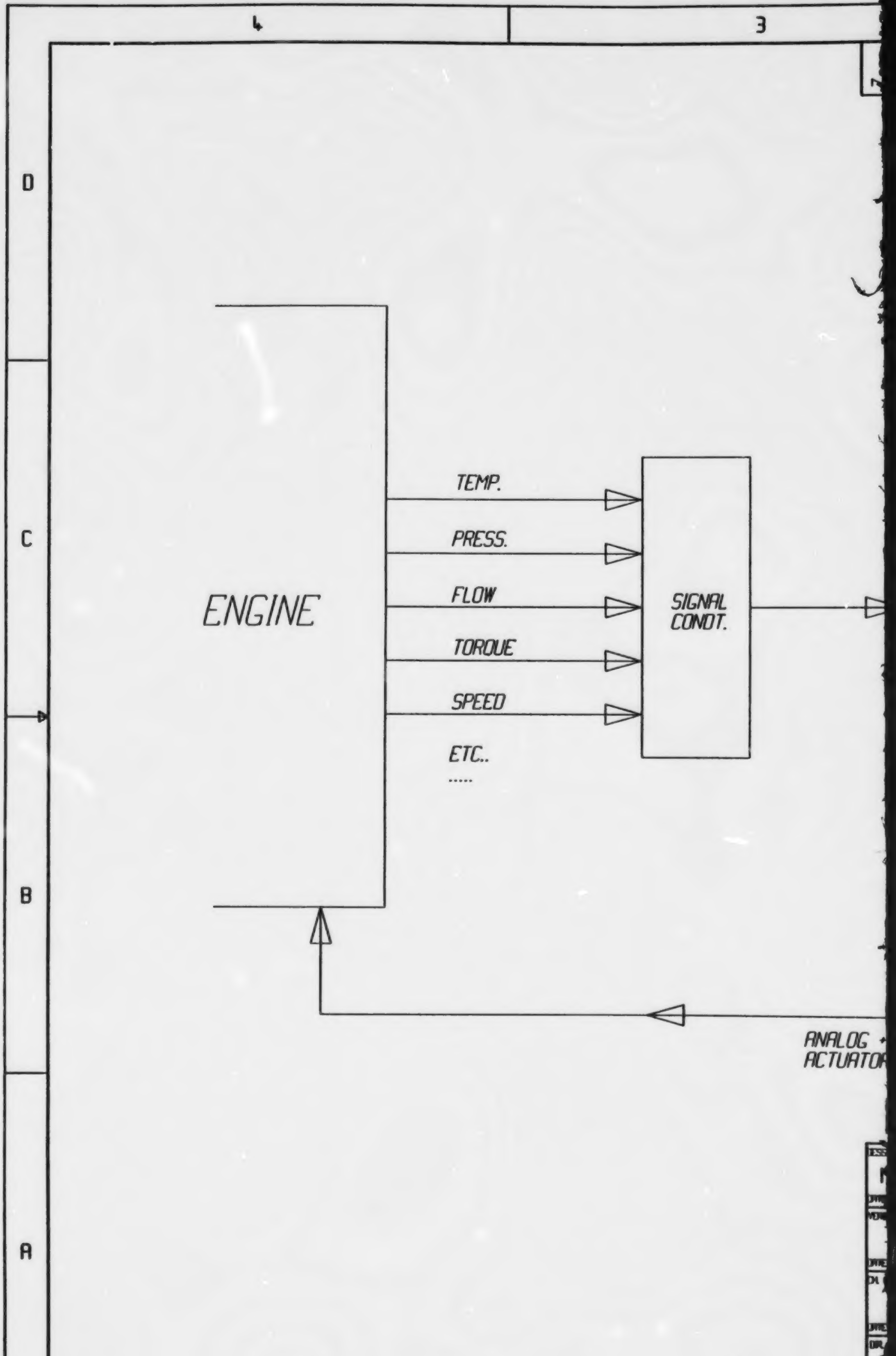


FIGURE 1 — COMPUTER DATA ACQUISITION SYSTEM (C-DAS)


4
3
D
C
B
A
ENGINE
TEMP.
PRESS.
FLOW
TORQUE
SPEED
ETC..
.....
SIGNAL
CONDT.
ANALOG +
ACTUATOR
4
3

2

1 **APPENDIX "A"**

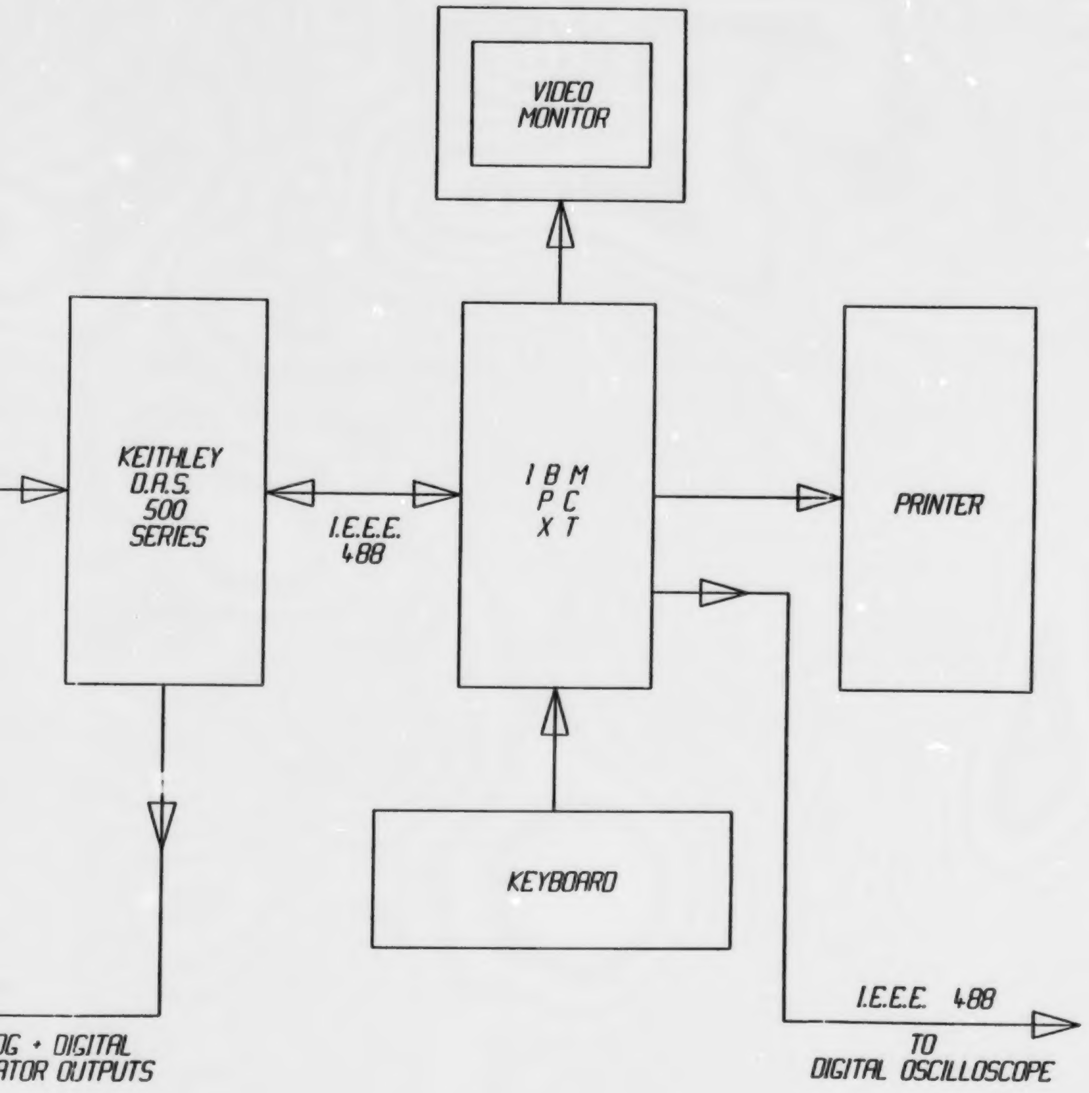
Zone	Repere / Item	(MA)-P/N-P/SICA 3 - 14 10 - 29 Piece n° / Part n°	P/N (MA) 001 Nom piece / Part name	P/N (MA) 047 Matiere / Raw Mat'l	P/N (MA) 062 Description	Masse Mass	P-SICA 003 Qu-Qty	P-MAMA 053 U-M	P-MAMA 037 Appro.

D

C

B

A


VIDEO MONITOR
KEITHLEY D.A.S. 500 SERIES
I.E.E.E. 488
IBM PC XT
PRINTER
KEYBOARD
I.E.E.E. 488
TO DIGITAL OSCILLOSCOPE
G + DIGITAL
ATOR OUTPUTS

DIMENSIONS ARE IN INCHES

DESSINATEUR
M.M'CHIRGUI
DATE 86.11.18
VERIFICATEUR
DATE
CH. GROUPE
DATE
DIR.
DATE

PROJECTION:

TOLERANCE ET FINI DE SURFACE
SAUF INDICATION CONTRAIRE
DEC.(MACH.) 000 = +/- 0.03
000.0 = +/- 0.02
000.00 = +/- 0.01
000.000 = +/- 0.005
DEC.(BRUT.) +/- .06
ANGLES: +/- 1/4 DEG. CHANFREIN +/- 2 DEG.
EBARDER 1/64
FINI DE SURFACE 125 MU IN.

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NO. REFERENCE

NO. ENSEMBLE/ASSEMBLY NO.

NO. MODELE

A2

NO. COMMANDE/SALES ORDER NO.

ECH.-SC.
NTS

BOMBARDIER INC.
DIVISION DES PRODUITS FERROVIAIRES ET DIESEL
RAIL AND DIESEL PRODUCTS DIVISION
MONTREAL, QUEBEC, CANADA

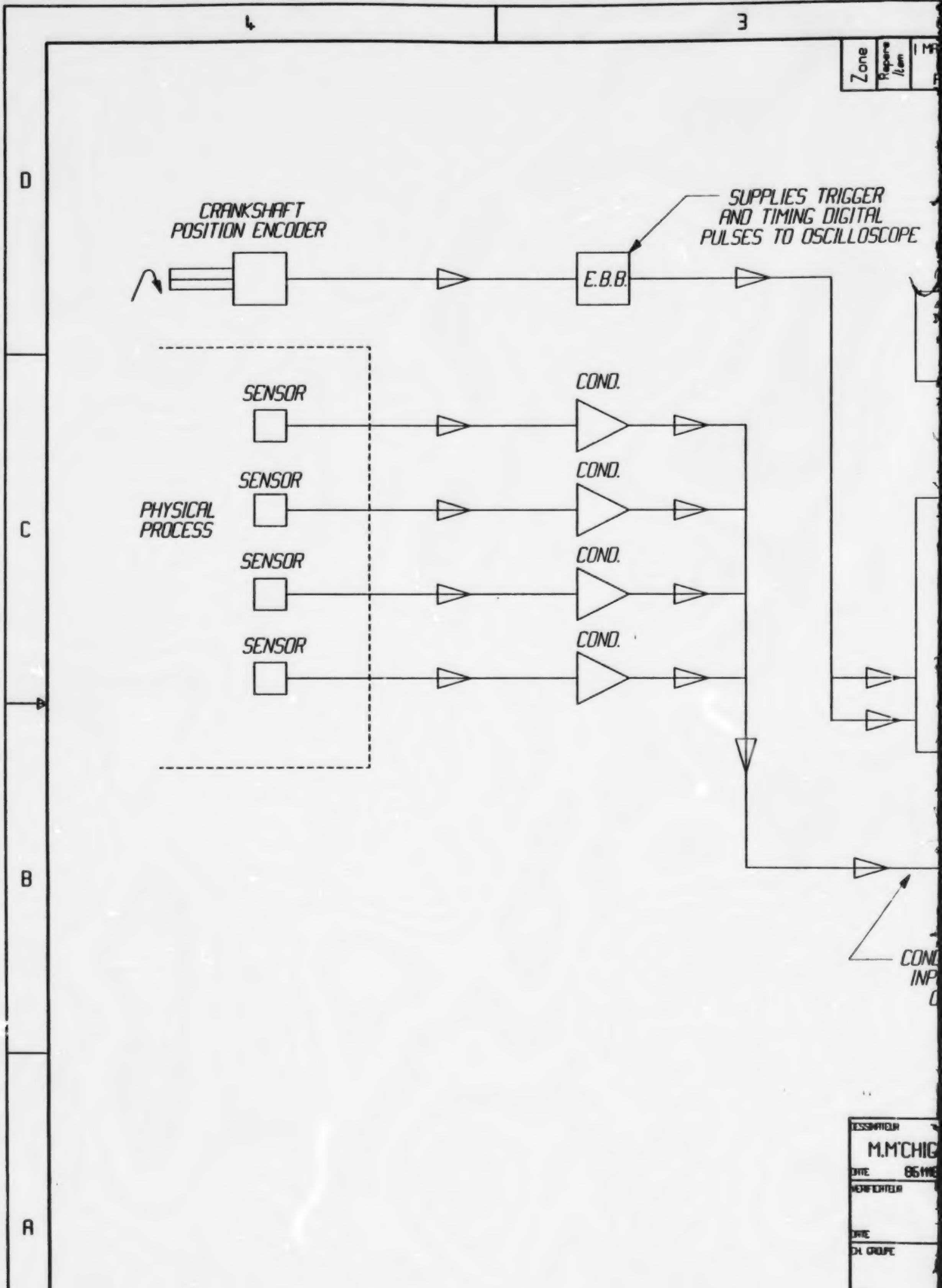
OBJET-SUBJECT
POUR-FOR

LOW SPEED
DATA ACCQUISITION SYSTEM
(LSDAS)

FOLIO
PLAN NO.-DRAWING NO.
R94-096007
REVISION

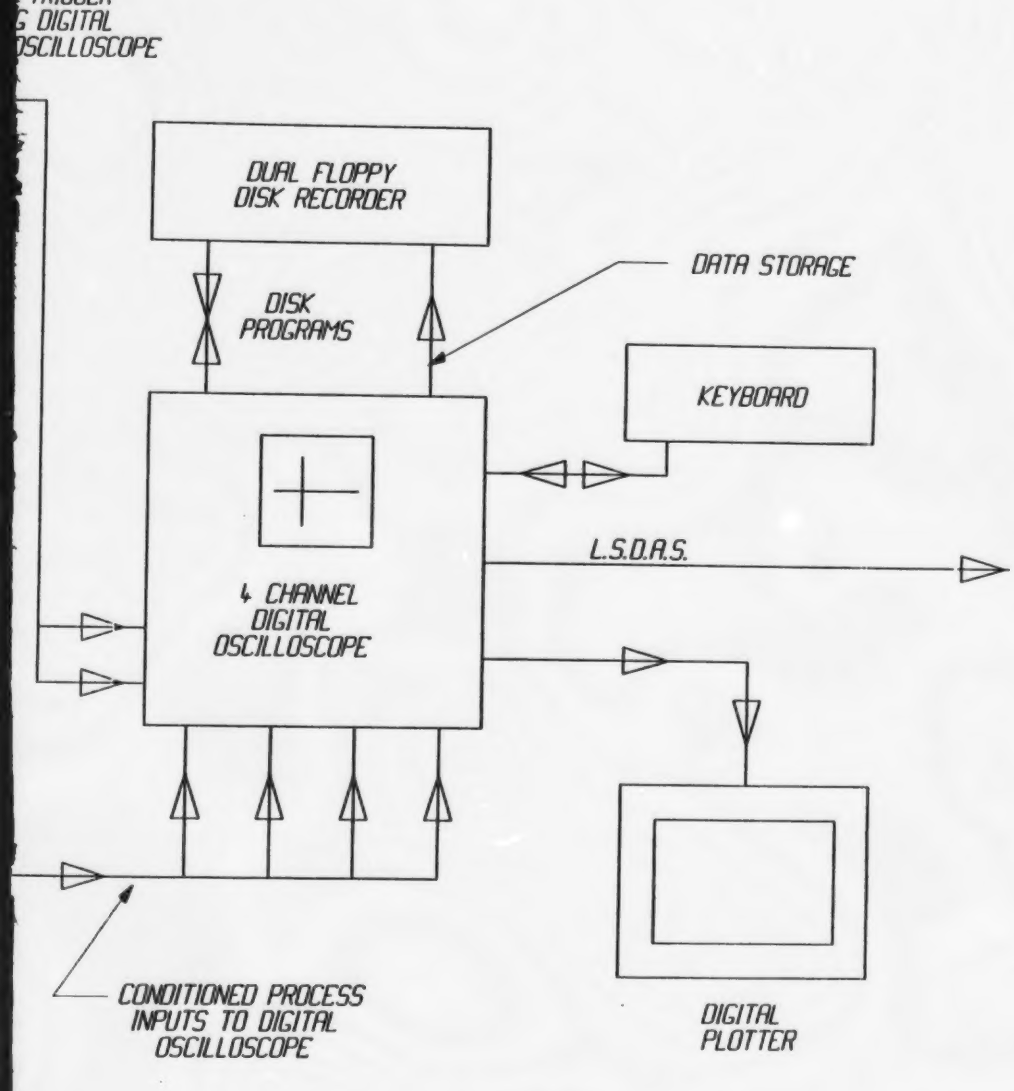
2

1 **FIGURE 2**


4
3
Zone
Repère
Item
D
C
B
A
CRANKSHAFT
POSITION ENCODER
SUPPLIES TRIGGER
AND TIMING DIGITAL
PULSES TO OSCILLOSCOPE
E.B.B.
PHYSICAL
PROCESS
SENSOR
SENSOR
SENSOR
SENSOR
COND.
COND.
COND.
COND.
COND
INP
DESSINATEUR
M.M'CHIG
DATE
8611
VERIFICATEUR
DATE
CH. GROUPE
DATE
DIR.
DATE

APPENDIX "A"

Zone	Repere / Item	(MA)-P/N-P/S(CA) 3 - 4 18 - 29 Piece n° / Part n°	P/N (MA) 001 Nom piece / Part name	P/N (MA) 047 Matiere / Raw Matl	P/N (MA) 062 Description	Masse / Mass	P-S(CA) 003 Qu-Qty	P-M(MA) 053 U-M	P-M(MA) 037 Approv.



TRIGGER
G DIGITAL
OSCILLOSCOPE
DUAL FLOPPY
DISK RECORDER
DATA STORAGE
DISK
PROGRAMS
KEYBOARD
L.S.D.A.S.
4 CHANNEL
DIGITAL
OSCILLOSCOPE
CONDITIONED PROCESS
INPUTS TO DIGITAL
OSCILLOSCOPE
DIGITAL
PLOTTER

DIMENSIONS ARE IN INCHES

DESSINATEUR
M.M'CHIGUI
DATE 861118
VERIFICATEUR
DATE
CH. GROUPE
DATE
DIR.
DATE

PROJECTION: ⊕ ⊏

TOLERANCE ET FINI DE SURFACE
SAUF INDICATION CONTRAIRE
DEC.(MACH.) 000 = +/- 0.03
000.0 = +/- 0.02
000.00 = +/- 0.01
000.000 = +/- 0.005
DEC.(BRUT.) +/- .06
ANGLES: +/- 1-4 DEG. CHANFREIN +/- 2 DEG.
EBARDER 1-64
FINI DE SURFACE 125 MU IN.

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NO. MODELE
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NO. COMMANDE/SALES ORDER NO.
ECH.-SC
NTS

BOMBARDIER INC.
DIVISION DES PRODUITS FERROVIAIRES ET DIESEL
RAIL AND DIESEL PRODUCTS DIVISION
MONTREAL, QUEBEC, CANADA

OBJET-SUBJECT
HIGH SPEED
DATA ACCQUISITION SYSTEM
(HSDAS)
POUR-FOR
FOLIO
PLAN NO.-DRAWING NO.
R94-096006
REVISION

FIGURE 3

```
ENGINE R&D                                   ENGINE DATA LOG
          1-251                      TEST CELL 5

Date: 860729         Time:  11 : 24 : 40         XHEN, [hrs]:       447
--------------------------------------------------------------------------

--------------------------------------------------------------------------

XSEN    rpm    698.789     XTDY    N-m    484.498     FFWT1   kg        9.551
FTENIN  C       29.794     CTDYOT  C       25.968     JTENOT  C        67.649
JTENIN  C       66.287     LTENOT  C       55.255     ATSHOP  C        25.490
ETPORT  C      299.836     ATCELL  C       31.468     ETSK    C        61.257
LTENIN  C       53.408     ATTANK  C       63.104     APSHOP kPa      395.166
SMOKE   volts    2.910     EPTANK kPa      -0.989     EPPORT kPa        5.973
APENIN kPa      24.980     LFEN    l/min  122.145     JFEN    l/min   145.834
AFEN    kg/s     0.100     FPENIN kPa     381.928     JPENOT kPa       15.289
LPENIN kPa     661.041

XSEN    rpm    698.043     XTDY    N-m    486.288     XLDY    kW       35.547
FFCO   kg/h     42.983     BMEP    bar      5.583     BSFC g/kw-h   1209.176
SMOKE bosch      0.000     AFEN kg/s        0.120     A:F RATIO -      10.036
BSAC kg/kw-h    12.136     TCEFF  -         0.000     TMEP bar          0.000
IMEP bar         0.000     PMEP bar         0.000     PMAX bar          0.000
NMECH %          0.000
--------------------------------------------------------------------------
```

```
ENGINE R&D                                   ENGINE DATA LOG
          1-251                      TEST CELL 5

Date: 860729         Time:  11 : 26 : 51         XHEN, [hrs]:       447
--------------------------------------------------------------------------

--------------------------------------------------------------------------

XSEN    rpm    698.239     XTDY    N-m    487.183     FFWT1   kg        8.021
FTENIN  C       30.096     CTDYOT  C       26.031     JTENOT  C        67.254
JTENIN  C       65.892     LTENOT  C       56.931     ATSHOP  C        25.552
ETPORT  C      300.997     ATCELL  C       29.857     ETSK    C        70.205
LTENIN  C       59.009     ATTANK  C       63.849     APSHOP kPa      395.776
SMOKE   volts    2.996     EPTANK kPa      -1.145     EPPORT kPa        0.964
APENIN kPa      24.429     LFEN    l/min  121.587     JFEN    l/min   145.496
AFEN    kg/s     0.100     FPENIN kPa     431.091     JPENOT kPa       14.526
LPENIN kPa     650.055

XSEN    rpm    697.964     XTDY    N-m    487.020     XLDY    kW       35.597
FFCO   kg/h     38.446     BMEP    bar      5.591     BSFC g/kw-h   1080.051
SMOKE bosch      0.000     AFEN kg/s        0.119     A:F RATIO -      11.143
BSAC kg/kw-h    12.035     TCEFF  -         0.000     TMEP bar          0.000
IMEP bar         0.000     PMEP bar         0.000     PMAX bar          0.000
NMECH %          0.000
--------------------------------------------------------------------------
```

FIGURE 4

APPENDIX "A"

Key to Mnemonics

INNHBO - Injection Nozzle Number of Holes
IPSIZE - Injection Pump SIZE
INHODI - Injection Nozzle HOle DIameter
INSPAN - Injection Nozzle SPray ANgle
IPTIMG - Injection Pump TIMinG
TCTYPE - TurboCharger TYPE
TCNRAR - TurboCharger Nozzle Ring ARea
TCNRAN - TurboCharger Nozzle Ring ANgle
TCDIAN - TurboCharger DIffuser ANgle
TCDIAR - TurboCharger DIffuser ARea

XHTIIN - Hours TIme IN
XHEN - Hours ENgine
XSEN - Speed ENgine
XTDY - Torque DYnamometer
XLDY - Load DYnamometer
(PME) - Pressure Mean Effective
XSTC - Speed TurboCharger
ATCELL - Air Temperature CELL
ATAM - Air Temperature AMbient
ATCRIN - Air Temperature CompRessor IN
ATACIN - Air Temperature AfterCooler IN
ATMFFE - Air Temperature ManiFold Free-End
ATMFDE - Air Temperature ManiFold Drive-End
ATR4IN - Air Temperature R4 IN
APAM - Air Pressure AMbient
APCRIN - Air Pressure CompRessor IN
APACIN - Air Pressure AfterCooler IN
APMF - Air Pressure ManiFold
AFENIN - Air Flow ENgine IN
LTPPOT - Lube Temp. PumP OuT
LTX3OT - Lube Temp. eXchanger 3 OuT
LTENRN - Lube Temp. ENgine ReturN
LPPPOT - Lube Press. PumP OuT
LPENIN - Lube Press. ENgine IN
LPENRN - Lube Press. ENgine ReturN
LPH1 - Lube Press. Header 1
LPH2 - Lube Press. Header 2
LPTCIN - Lube Press. TurboCharger IN
LPGV - Lube Press. GoVernor
LFCO - Lube Flow COnsumption
FTENIN - Fuel Temp. ENgine IN
FPENIN - Fuel Press. ENgine IN
FFCO - Fuel Flow COnsumption
(BSFC) - Brake Specific Fuel Consumption (uncorrected)
FDRB - Fuel Displacement Right Bank
FDLB - Fuel Displacement Left Bank
XT?? - eXhaust Temp cylinder ?? eg. XTL1
XP?? - cylnder Pressure cylinder ?? eg. XPL1
ETT1IN - Exhaust Temp. Turbine sector 1 IN
ETT2IN - Exhaust Temp. Turbine sector 2 IN
ETT3IN - Exhaust Temp. Turbine sector 3 IN
ETSK - Exhaust Temp StacK
ETCC - Exhaust Temp. CrankCase
EPCC - Exhaust Press. CrankCase

EPT0IN - avg Exhaust Press. Turbine IN
EPSK - Exhaust Press. StacK
EFBB - Exhaust Flow Blow-By
EOSKS1 - Exhaust Opacity StacK S1 (bosch)
EOSKS2 - Exhaust Opacity StacK S2 (opacity)
CTCW - Coolant Temp Cold Well
CTHW - Coolant Temp. Hot Well
CTDYIN - Coolant Temp. DYno IN
CTDYOT - Coolant Temp. DYno OuT
CTP2OT - Coolant Temp. Pump 2 OuT
CTX1OT - Coolant Temp. eXchanger 1 OuT
CTX2OT - Coolant Temp. eXchanger 2 OuT
CTX3OT - Coolant Temp. eXchanger 3 OuT
CPP2OT - Coolant Press. Pump 2 OuT
CPDYIN - Coolant Press. DYno IN
CFDY - Coolant Flow DYno
CFP2 - Coolant Flow Pump 2
CFX1 - Coolant Flow eXchanger 1
CFX2 - Coolant Flow eXchanger 2
CFX3 - Coolant Flow eXchanger 3
CTX0IN - Coolant Temp. eXchanger 0 IN
CTX0OT - Coolant Temp. eXchanger 0 OuT
JTTCOT - Jacket Temp. TurboCharger OuT
JTPPIN - Jacket Temp. PumP IN
JTENIN - Jacket Temp. ENgine IN
JTENRN - Jacket Temp. ENgine ReturN
JTENOT - Jacket Temp. ENgine OuT
JTACIN - Jacket Temp. AfterCooler IN
JTACOT - Jacket Temp. AfterCooler OuT
JTX0IN - Jacket Temp. eXchanger 0 IN
JTX0OT - Jacket Temp. eXchanger 0 OuT
JTX1IN - Jacket Temp. eXchanger 1 IN
JTX1OT - Jacket Temp. eXchanger 1 OuT
JTX2IN - Jacket Temp. eXchanger 2 IN
JTX2OT - Jacket Temp. eXchanger 2 OuT
JTICOT - Jacket Temp. Intermediate Casing OuT
JTM1OT - Jacket Temp. Manifold 1 OuT
JTM2OT - Jacket Temp. Manifold 2 OuT
JTGCOT - Jacket Temp. Gas Casing OuT
JPPPIN - Jacket Press. PumP IN
JPPPOT - Jacket Press. PumP OuT
JPACIN - Jacket Press. AfterCooler IN
JPENOT - Jacket Press. ENgine OuT
JPACOT - Jacket Press. AfterCooler OuT
JPICOT - Jacket Press. Intermediate Casing OuT
JPM1OT - Jacket Press. Manifold 1 OuT
JPM2OT - Jacket Press. Manifold 2 OuT
JPGCOT - Jacket Press. Gas Casing OuT
JFAC - Jacket Flow AfterCooler
JFIC - Jacket Flow Intermediate Casing
JFX0 - Jacket Flow eXchanger 0
JFX1 - Jacket Flow eXchanger 1
JFENOT - Jacket Flow ENgine OuT
JFGC - Jacket Flow Gas Casing

FIGURE 4-A.1

Key to Mnemonics (in Alphabetical Order)

(BSFC) - Brake Specific Fuel Consumption (uncorrected)
(FME) - Pressure Mean Effective
AFENIN - Air Flow ENgine IN
APACIN - Air Pressure AfterCooler IN
APAM - Air Pressure Ambient
APCRIN - Air Pressure CompRessor IN
APMF - Air Pressure ManiFold
ATACIN - Air Temperature AfterCooler IN
ATAM - Air Temperature AMbient
ATCELL - Air Temperature CELL
ATCRIN - Air Temperature CompRessor IN
ATMFDE - Air Temperature ManiFold Drive-End
ATMFFE - Air Temperature ManiFold Free-End
ATR4IN - Air Temperature R4 IN
CFDY - Coolant Flow DYno
CFP2 - Coolant Flow Pump 2
CFX1 - Coolant Flow eXchanger 1
CFX2 - Coolant Flow eXchanger 2
CFX3 - Coolant Flow eXchanger 3
CPDYIN - Coolant Press. DYno IN
CPP2OT - Coolant Press. Pump 2 OuT
CTCW - Coolant Temp Cold Well
CTDYIN - Coolant Temp. DYno IN
CTDYOT - Coolant Temp. DYno OuT
CTHW - Coolant Temp. Hot Well
CTP2OT - Coolant Temp. Pump 2 OuT
CTX0IN - Coolant Temp. eXchanger 0 IN
CTX0OT - Coolant Temp. eXchanger 0 OuT
CTX1OT - Coolant Temp. eXchanger 1 OuT
CTX2OT - Coolant Temp. eXchanger 2 OuT
CTX3OT - Coolant Temp. eXchanger 3 OuT
EFBB - Exhaust Flow Blow-By
EOSKS1 - Exhaust Opacity Stack S1 (bosch)
EOSKS2 - Exhaust Opacity Stack S2 (opacity)
EPCC - Exhaust Press. CrankCase
EPST - Exhaust Press. Stack
EPT0IN - avg Exhaust Press. Turbine IN
ETCC - Exhaust Temp. CrankCase
ETST - Exhaust Temp Stack
ETT1IN - Exhaust Temp. Turbine sector 1 IN
ETT2IN - Exhaust Temp. Turbine sector 2 IN
ETT3IN - Exhaust Temp. Turbine sector 3 IN
FDLB - Fuel Displacement Left Bank
FDRB - Fuel Displacement Right Bank
FFCO - Fuel Flow COnsumption
FPENIN - Fuel Press. ENgine IN
FTENIN - Fuel Temp. ENgine IN
INHODI - Injection Nozzle HOle DIameter
INNHSO - Injection Nozzle Number of Holes
INSPAN - Injection Nozzle SPray ANgle
IPSIZE - Injection Pump SIZE
IPTIMG - Injection Pump TIMinG
JFAC - Jacket Flow AfterCooler
JFENOT - Jacket Flow ENgine OuT

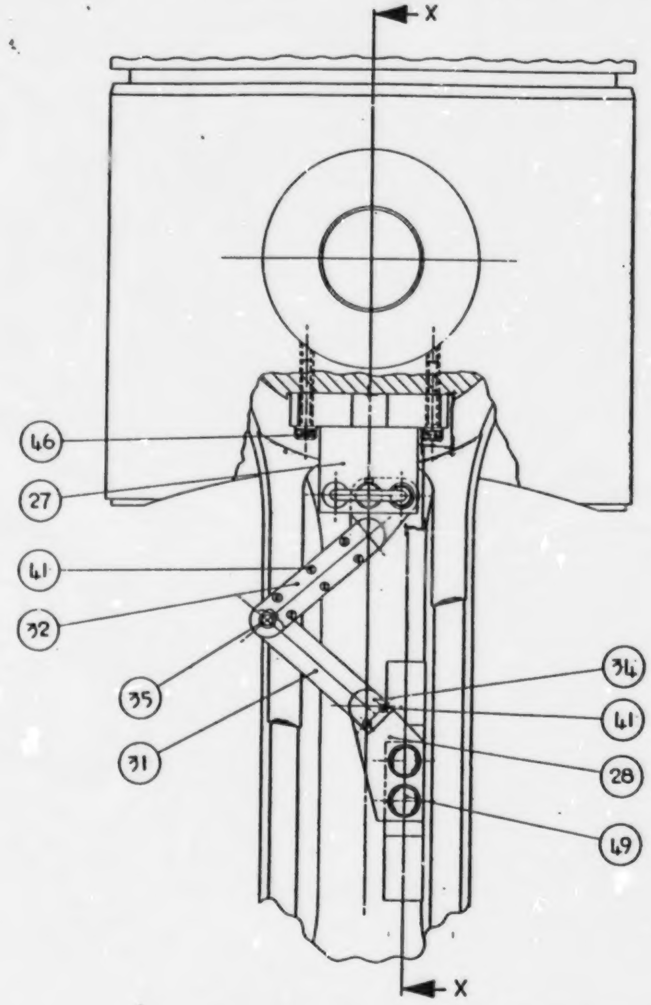
JFGC - Jacket Flow Gas Casing
JFIC - Jacket Flow Intermediate Casing
JFX0 - Jacket Flow eXchanger 0
JFX1 - Jacket Flow eXchanger 1
JPACIN - Jacket Press. AfterCooler IN
JPACOT - Jacket Press. AfterCooler OuT
JPENOT - Jacket Press. ENgine OuT
JPGCOT - Jacket Press. Gas Casing OuT
JPICOT - Jacket Press. Intermediate Casing OuT
JPM1OT - Jacket Press. Manifold 1 OuT
JPM2OT - Jacket Press. Manifold 2 OuT
JPPPIN - Jacket Press. PumP IN
JPPPOT - Jacket Press. PumP OuT
JTACIN - Jacket Temp. AfterCooler IN
JTACOT - Jacket Temp. AfterCooler OuT
JTENIN - Jacket Temp. ENgine IN
JTENOT - Jacket Temp. ENgine OuT
JTENRN - Jacket Temp. ENgine ReturN
JTGCOT - Jacket Temp. Gas Casing OuT
JTICOT - Jacket Temp. Intermediate Casing OuT
JTM1OT - Jacket Temp. Manifold 1 OuT
JTM2OT - Jacket Temp. Manifold 2 OuT
JTPPIN - Jacket Temp. PumP IN
JTTCOT - Jacket Temp. TurboCharger OuT
JTX0IN - Jacket Temp. eXchanger 0 IN
JTX0OT - Jacket Temp. eXchanger 0 OuT
JTX1IN - Jacket Temp. eXchanger 1 IN
JTX1OT - Jacket Temp. eXchanger 1 OuT
JTX2IN - Jacket Temp. eXchanger 2 IN
JTX2OT - Jacket Temp. eXchanger 2 OuT
LFCO - Lube Flow COnsumption
LPENIN - Lube Press. ENgine IN
LPENRN - Lube Press. ENgine ReturN
LPGV - Lube Press. GoVernor
LPH1 - Lube Press. Header 1
LPH2 - Lube Press. Header 2
LPPPOT - Lube Press. PumP OuT
LPTCIN - Lube Press. TurboCharger IN
LTENRN - Lube Temp. ENgine ReturN
LTPPOT - Lube Temp. PumP OuT
LTX3OT - Lube Temp. eXchanger 3 OuT
TCDIAN - TurboCharger DIffuser ANgle
TCDIAR - TurboCharger DIffuser ARea
TCNRAN - TurboCharger Nozzle Ring ANgle
TCNRAR - TurboCharger Nozzle Ring ARea
TCTYPE - TurboCharger TYPE
XHEN - Hours ENgine
XHTIIN - Hours TIme IN
XLDY - Load DYnamometer
XP?? - cylinder Pressure cylinder ?? eg. XPL1
XSEN - Speed ENgine
XSTC - Speed TurboCharger
XT?? - eXhaust Temp cylinder ?? eg. XTL1
XTDY - Torque DYnamometer

FIGURE 4-A.2

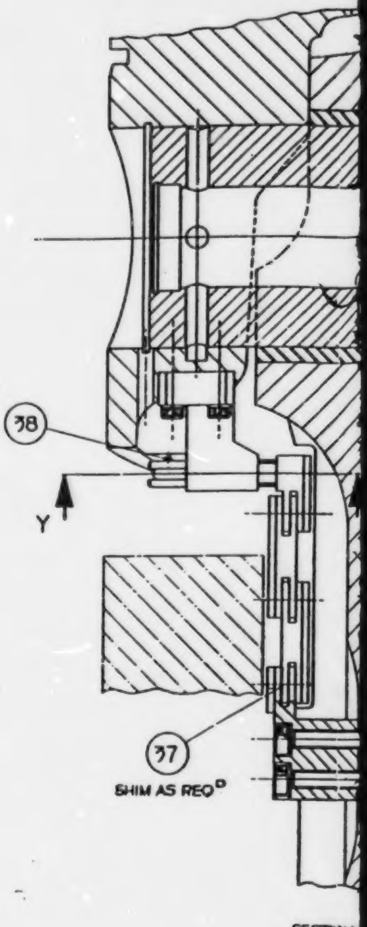
APPENDIX "B"

ENGINE QUALIFICATION

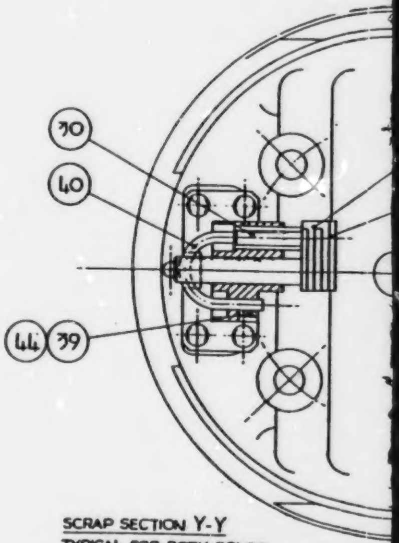
Fig. 1 Swing link assembly drawing
Fig. 2 Instrumented piston/rod assembly
Fig. 3 Piston and connecting rod flexible link
Fig. 4 Cylinder liner (instrumentation preparation)



TYPICAL ARRANGEMENT FOR BOTH B2400 & 251 ENGINES



SECTION
B2400 E



SCRAP SECTION Y-Y
TYPICAL FOR BOTH B2400
& 251 ENGINES

NOTES

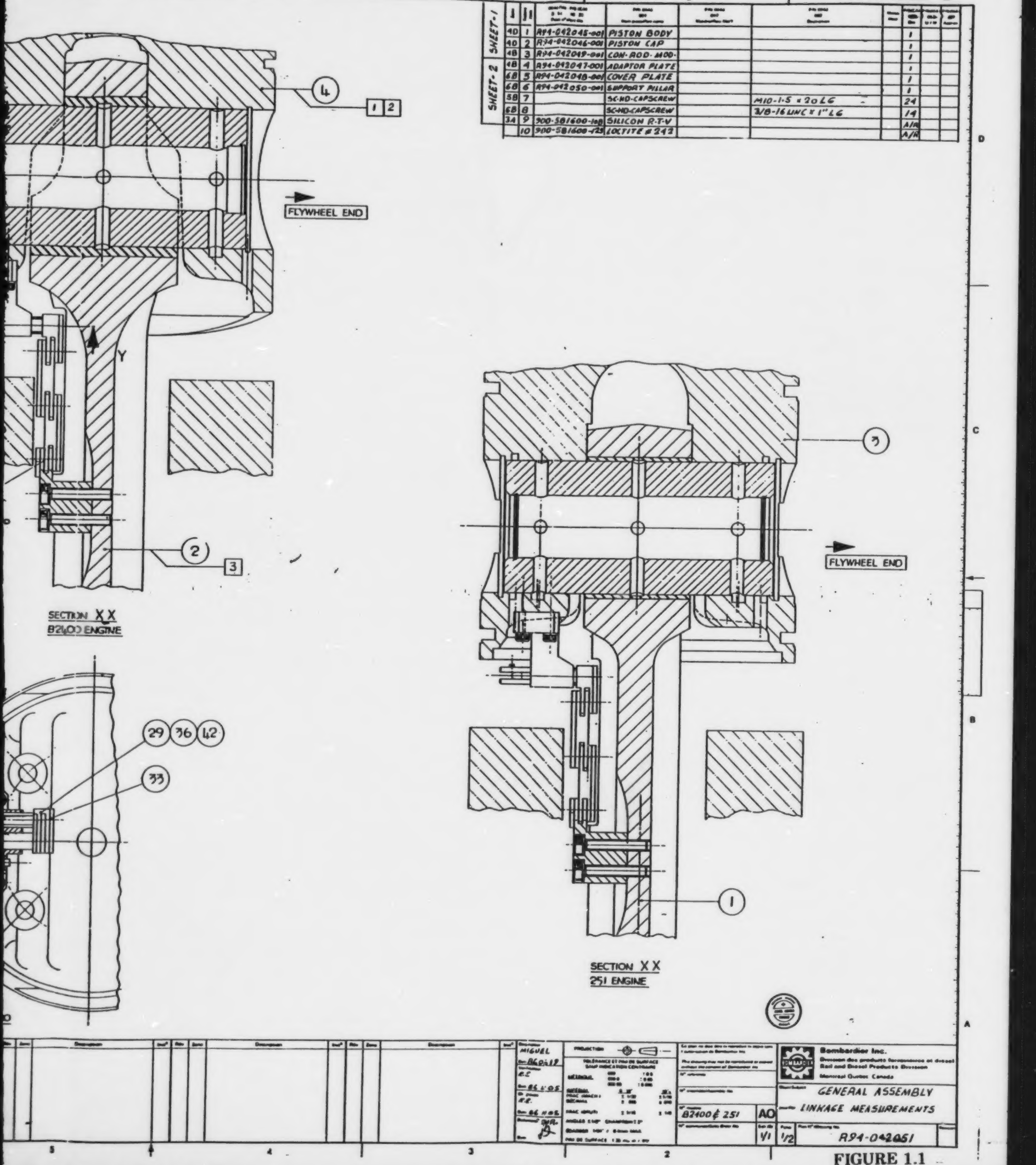
1. USE LOW MELTING POINT (185°C) SOLDER (60% TIN 40% LEAD) TO ATTACH BOWDEN CABLE (ITEM 40) TO LOCATION PIN (ITEM 30)

2. TO KEEP BOWDEN CABLE AS SHORT AS POSSIBLE PUSH SLIDING PIVOT (ITEM 29) AS FAR AS IT WILL GO INTO SLIDE BLOCK (ITEM 27) ADJUST THE BOWDEN CABLE TO JUST TOUCH THE BOTTOM OF THE SLOT IN THE SLIDING PIVOT & THEN TIGHTEN CLAMP (ITEM 39)

3. USE 'LOCTITE' NUTLOCK 242 OR 'PERMABOND) 113 ON ALL LINKAGE ASSEMBLY SCREWS & BOLTS. *ITEM 10*

4. BOLT TIGHTENING TORQUES:-
SLIDE BLOCK BOLTS (ITEM 46) M6 - 15 N/M
FIXED PIVOT BOLTS (ITEM 49) M8 - 35 N/M

5. *ITEMS ECLOSED IN A SQUARE ☐ ARE BY BOMBARDIER AND ARE SHOWN IN B/M*


4
1 2
FLYWHEEL END
Y
2
3
SECTION XX
B2400 ENGINE
29
36
42
33
3
FLYWHEEL END
1
SECTION XX
251 ENGINE
5
4
3
2
D
C
B
A

SHEET-1	4D	1	R94-042045-001	PISTON BODY		1
SHEET-1	4D	2	R94-042046-001	PISTON CAP		1
SHEET-2	4B	3	R94-042049-001	CON-ROD-MOD-		1
SHEET-2	4B	4	R94-042047-001	ADAPTOR PLATE		1
SHEET-2	6B	5	R94-042048-001	COVER PLATE		1
SHEET-2	6B	6	R94-042050-001	SUPPORT PILLAR		1
SHEET-2	5B	7		SC-HD-CAPSCREW	M10-1-5 × 20LG	24
SHEET-2	6B	8		SC-HD-CAPSCREW	3/8-16 UNC × 1" LG	14
SHEET-2	3A	9	900-581600-108	SILICON R-T-V		A/R
		10	900-581600-125	LOCTITE # 242		A/R

MIGUEL
86-04-19
E.C
86-4-05
R.R.
86-4-05

PROJECTION

B2400 & 251
AO
1/1
1/2

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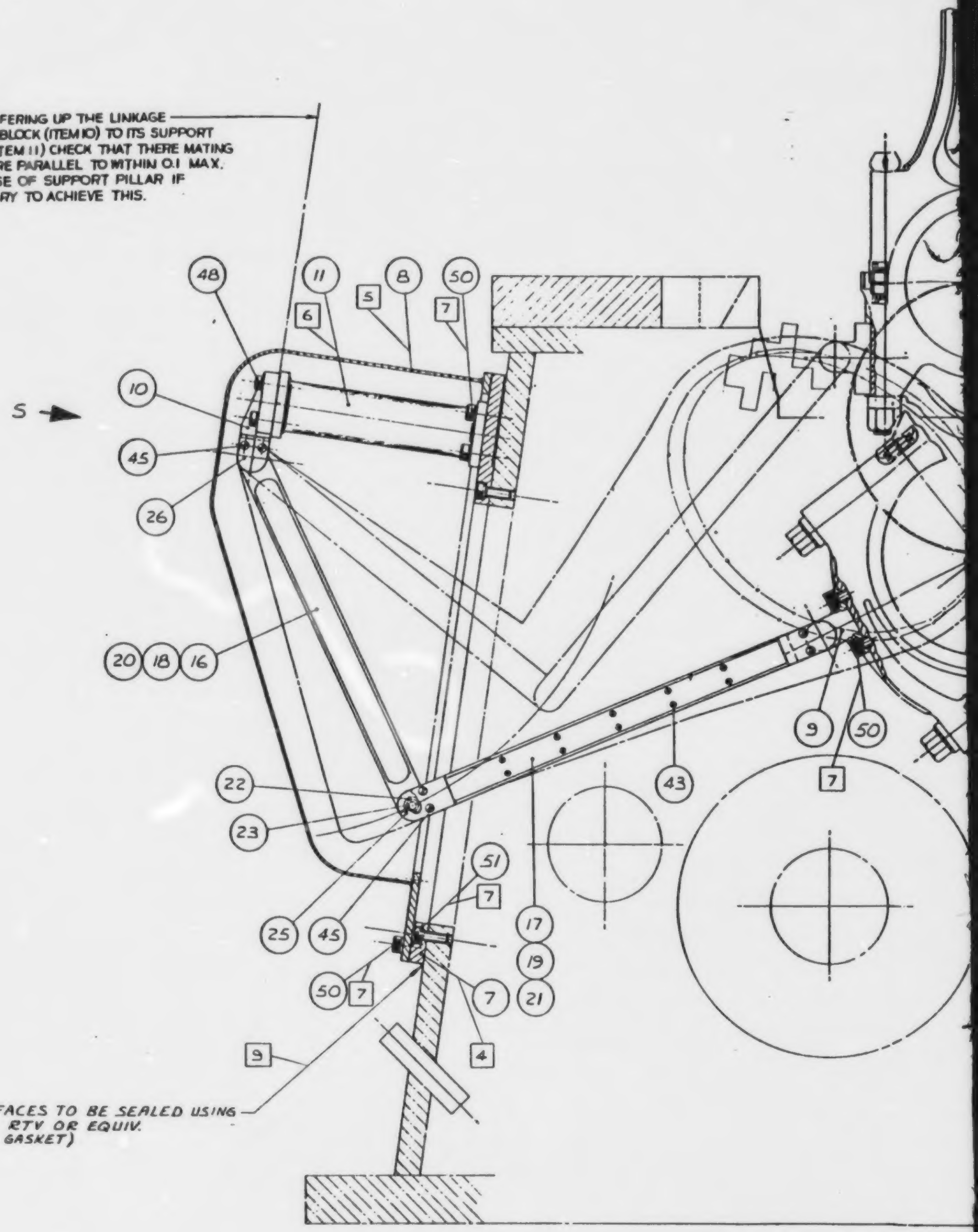
Montreal Quebec Canada

GENERAL ASSEMBLY
LINKAGE MEASUREMENTS

R94-042051

FIGURE 1.1

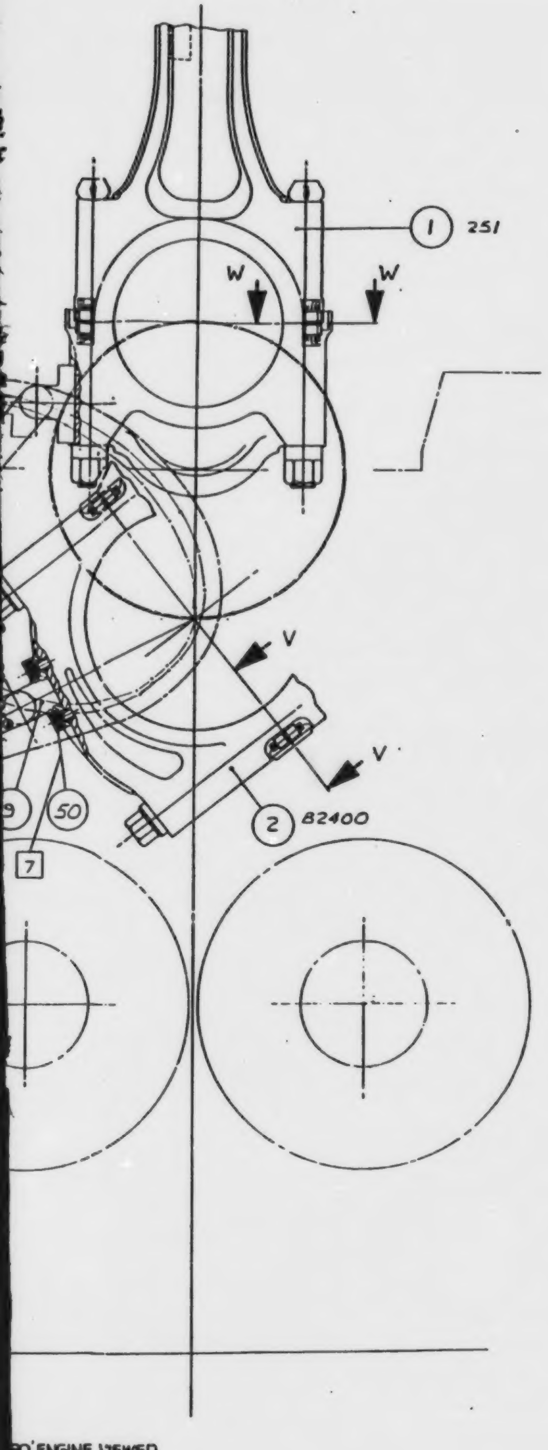
WHEN OFFERING UP THE LINKAGE ANCHOR BLOCK (ITEM 10) TO ITS SUPPORT PILLAR (ITEM 11) CHECK THAT THERE MATING FACES ARE PARALLEL TO WITHIN 0.1 MAX. SHIM BASE OF SUPPORT PILLAR IF NECESSARY TO ACHIEVE THIS.


48
11
8
50
6
5
7
10
S
45
26
20
18
16
9
50
7
43
22
23
51
7
17
19
21
25
45
50
7
7
9
4

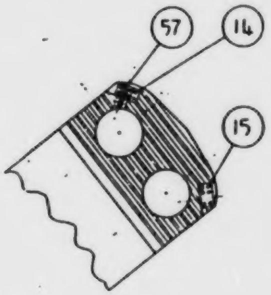
THESE FACES TO BE SEALED USING SILICON RTV OR EQUIV. (USE NO GASKET)

SECTION THRO' ENGINE VIEWED FROM FLYWHEEL END.
TYPICAL ARRANGEMENT FOR BOTH B2400 & 251 ENGINES

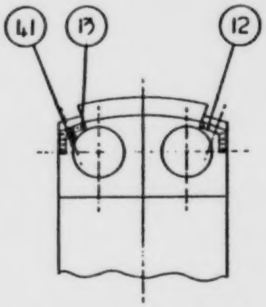
Rev	Date	Description	Init'	Rev	Date	Description	Init'	Rev	Date	Description	Init'	Rev	Date	Description	Init'	Rev	Date	Description



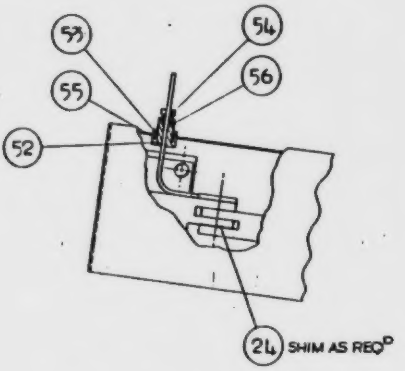
RO' ENGINE VIEWED
HEEL END.
RANGEMENT FOR
O & 251 ENGINES



SCRAP SECTION V-V
SCALE :- FULL SIZE



SCRAP SECTION W-W
SCALE : FULL SIZE



SCRAP VIEW ON ARROW S

NOTES :-

1. USE 'LOCKTITE' NUTLOCK 242 OR 'PERMABOND' 113 ON ALL LINKAGE ASSEMBLY SCREWS & BOLTS

2. BOLT TIGHTENING TORQUES :-
PIVOT BLOCK BOLTS (ITEM 50) M10 - 69 N/M
ANCHOR BLOCK BOLTS (ITEM 48) M8 - 35 N/M

3. BEFORE TIGHTENING CABLE GLAND NUT (ITEM 54) PULL THE CABLE THRO' THE BULKHEAD CONNECTOR (ITEM 52) UNTIL ALL SLACK IS TAKEN UP, THEN PUSH 10MM OF CABLE BACK THRO' THE GLAND TO RELIEVE TENSION. TIGHTEN NUT UNTIL CABLE IS JUST NIPPED UP.

M.6
86 06 17
R.E
86 11 06
R.E.
86 11 06

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Montreal, Quebec, Canada

GENERAL ASSEMBLY
LINKAGE MEASUREMENTS

B2400 & 251
1/2
2/2
R34-042051

FIGURE 1.2

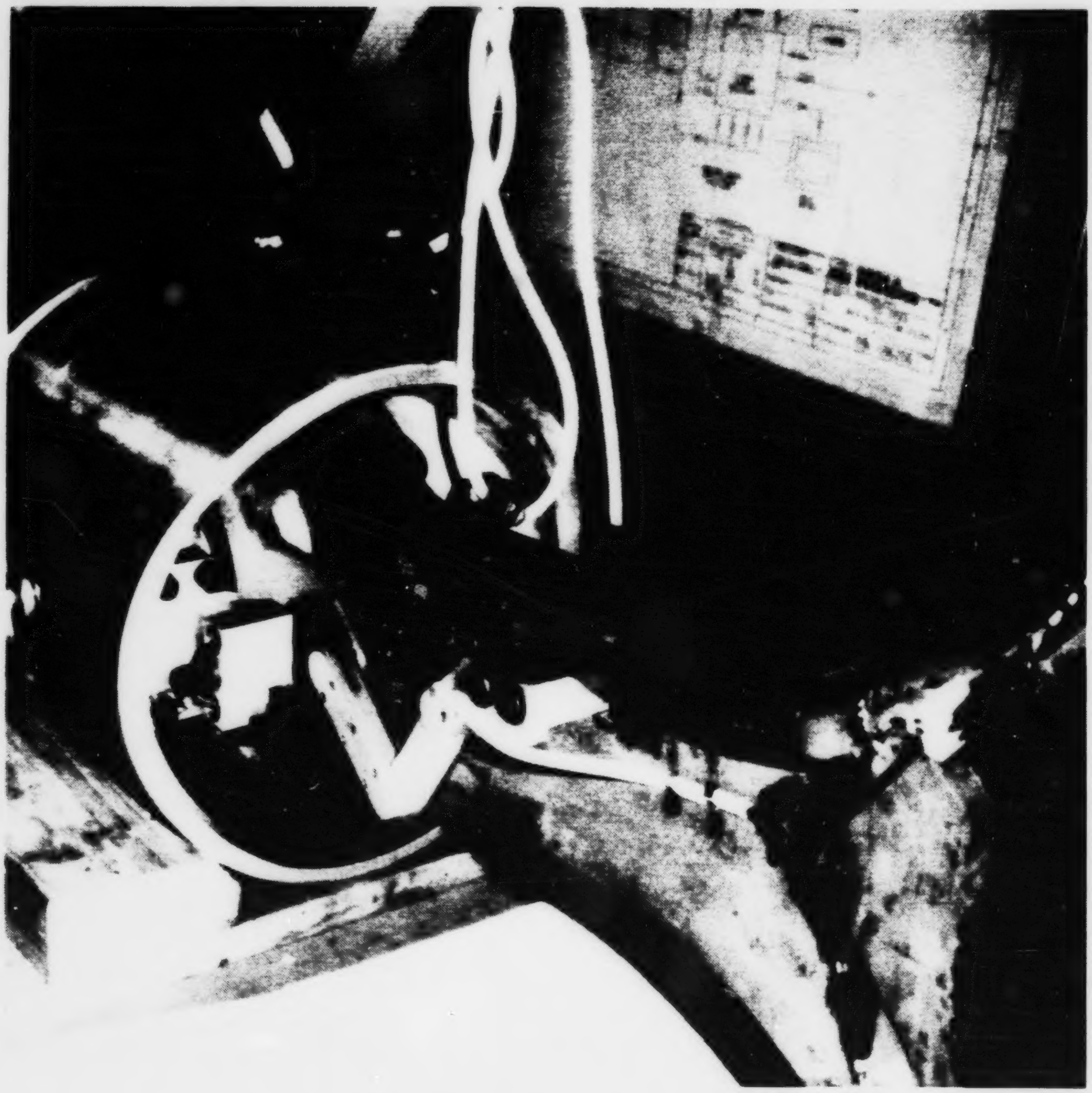


FIGURE 2 — SWING LINK APPARATUS
SHOWING INSTRUMENTATION

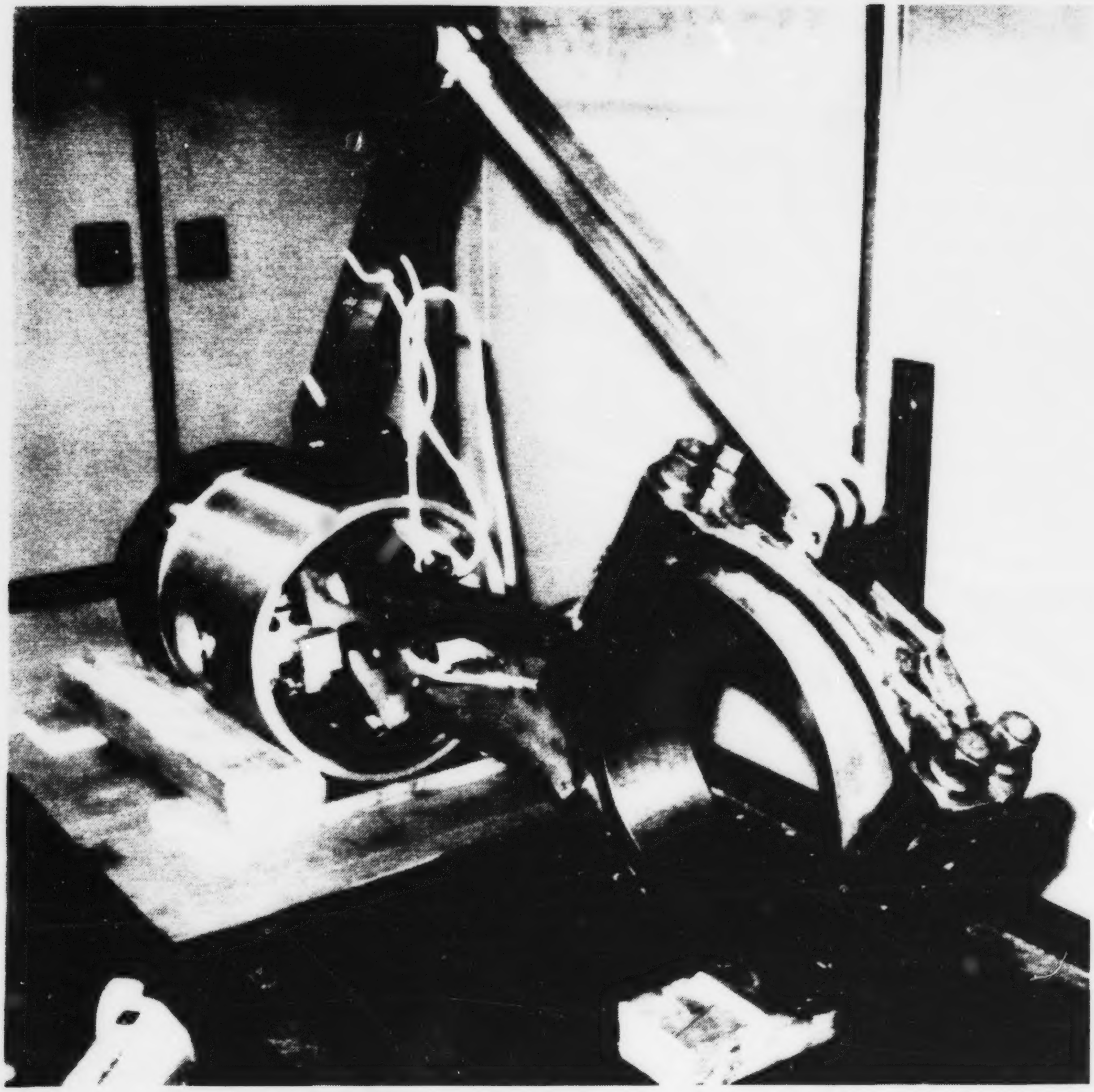
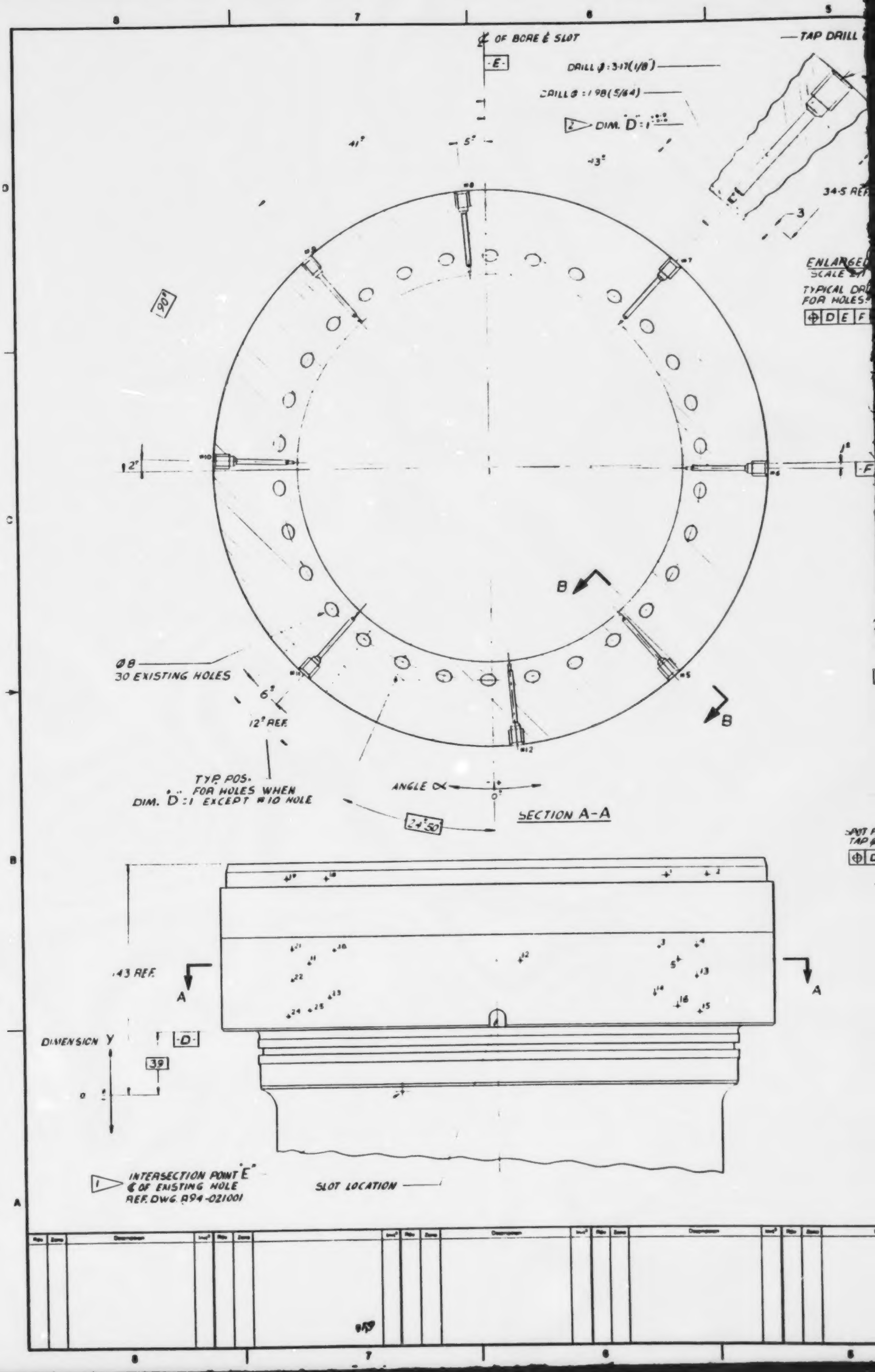
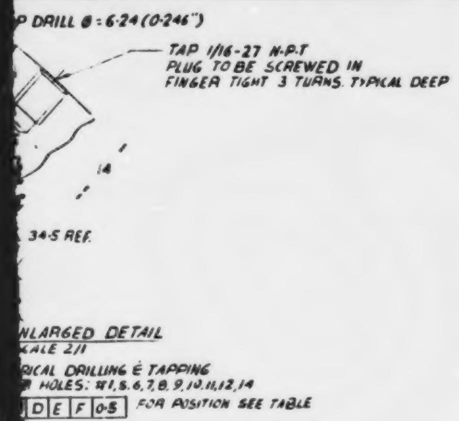


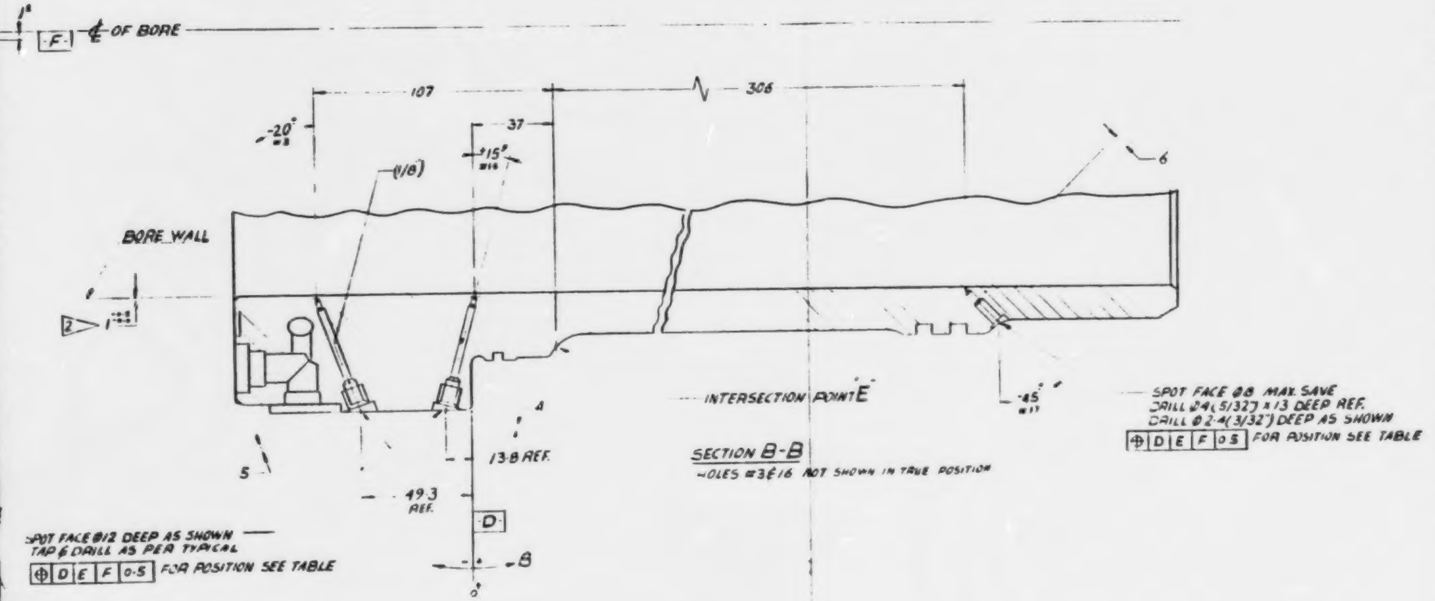
FIGURE 3 – SWING LINK APPARATUS
FITTED TO PISTON AND ROD ASSEMBLY


8
7
6
5
D
C
B
A
℄ OF BORE & SLOT
-E-
DRILL Ø:3.17(1/8")
DRILL Ø:1.98(5/64)
2 DIM. "D":1 ±0.0/0.0
5°
41°
3°
TAP DRILL
34.5 REF
3
ENLARGED
SCALE 2/1
TYPICAL DRI
FOR HOLES:
⊕ D E F
90°
#8
#9
#7
#10
#6
#11
#5
#12
2°
2°
-F-
B
B
Ø8
30 EXISTING HOLES
6°
12° REF.
TYP. POS. "•" FOR HOLES WHEN DIM. "D":1 EXCEPT #10 HOLE
ANGLE ∝
0°
24°50'
SECTION A-A
SPOT F
TAP Ø
⊕ D
19
18
1
2
21
20
11
22
23
24
25
12
3
4
5
13
14
16
15
43 REF.
A
A
DIMENSION Y
-D-
39
0
1 INTERSECTION POINT "E" ℄ OF EXISTING HOLE REF. DWG. A94-021001
SLOT LOCATION

A94-021004	CYL. LINER SUB-ASSY


P DRILL Ø: 6·24(0·246")
TAP 1/16-27 N.P.T
PLUG TO BE SCREWED IN
FINGER TIGHT 3 TURNS. TYPICAL DEEP
14
34·5 REF.
NLARGED DETAIL
SCALE 2/1
PICAL DRILLING É TAPPING
R HOLES: #1,5,6,7,8,9,10,11,12,14
D E F 0·5 FOR POSITION SEE TABLE

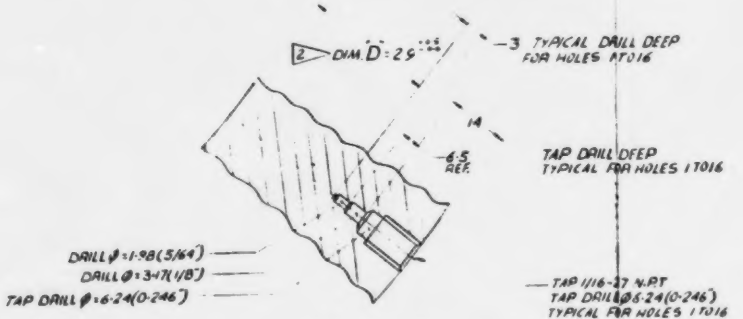
HOLE NUMBER	DIMENSION Y	DIMENSION "D"	ANGLE α	ANGLE β	HOLES QTY
1	+134	1	-39°	0°	1
2	+134	29	+51°	0°	1
3	+107	1	+30°	+20	1
4	+89	29	+46°	0°	1
5 TO 12	+80	1	SECTION A-A	0°	8
13	+70	29	+46	0°	1
14	+59	1	-34° 30'	0°	1
15	+48	29	+47°	0°	1
16	+37	1	+40° 30'	-15	1
17	-306	1	+45°	+45°	1
18	+134	1	-39°	0°	1
19	+134	29	-51°	0°	1
20	+107	1	-30°	+20°	1
21	+89	29	-48°	0°	1
22	+70	29	-48°	0°	1
23	+59	1	-37° 30'	0°	1
24	+48	29	-51°	0°	1
25	+37	1	-43°	-15°	1
26	-306	1	-45°	+45°	1


F
℄ OF BORE
107
306
37
-20°
(1/8)
+15°
6
BORE WALL
2
INTERSECTION POINT "E"
4
45°
5
13·8 REF.
49·3 REF.
D
β
0°

SPOT FACE Ø8 MAX. SAVE
DRILL 24(5/32") × 13 DEEP REF.
DRILL Ø 2·4(3/32") DEEP AS SHOWN
⊕ D E F 0·5 FOR POSITION SEE TABLE

SECTION B-B
HOLES #3 É 16 NOT SHOWN IN TRUE POSITION

SPOT FACE Ø12 DEEP AS SHOWN
TAP É DRILL AS PER TYPICAL
⊕ D E F 0·5 FOR POSITION SEE TABLE


2 DIM. D: 29
3 TYPICAL DRILL DEEP FOR HOLES 1 TO 16
14
6·5 REF.
TAP DRILL DEEP TYPICAL FOR HOLES 1 TO 16
DRILL Ø: 1·98(5/64")
DRILL Ø: 3·17(1/8")
TAP DRILL Ø: 6·24(0·246")
TAP 1/16-27 N.P.T
TAP DRILL Ø 6·24(0·246")
TYPICAL FOR HOLES 1 TO 16

ENLARGED DETAIL
SCALE 2/1
TYPICAL DRILLING É TAPPING
FOR HOLES # 2,4,13,15
⊕ D E F 0·5 FOR POSITION SEE TABLE

NOTES.

1. EXISTING INTERSECTION POINT "E" TO BE CHECKED PRIOR TO DRILLING HOLES OF TABLE. TO BE TRUE WITHIN 1°
2. IDEAL CONDITION OF DEPTH "D" TO BE WITHIN $^{+0.5}_{-0.0}$ FROM BORE WALL TO TIP OF DRILL. USE STANDARD GRINDING TIP FOR THIS APPLICATION. DO NOT GRIND DRILL BY HAND.
3. REMOVE SHARP EDGES.

UNTOLERANCED DIM. LOCATING TP ARE BASIC.

DIMENSIONS IN MILLIMETRES.

MIGUEL
83 11

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Division des produits ferroviaires et diesel
Rail and Diesel Products Division
Montréal Québec Canada

A94-021004
B2400
AO
CYLINDER LINER
MACHINING FOR INSTRUMENTATION OF TEMPERATURE.
1/1
1
A94-050008

FIGURE 4

APPENDIX "C"

FUELS AND LUBRICANTS LABORATORY

Fig. 1 Fuels and lubricants laboratory

Fig. 2 Flow and instrument diagram

Fig. 3 Outline fuel blending system

Fig. 4 Equipment and piping arrangement

Fig. 5 Test equipment cabinet

Fig. 6 Lubricating oil maintenance instruction/specification

Fig. 7 Fuel oil maintenance instruction/specification

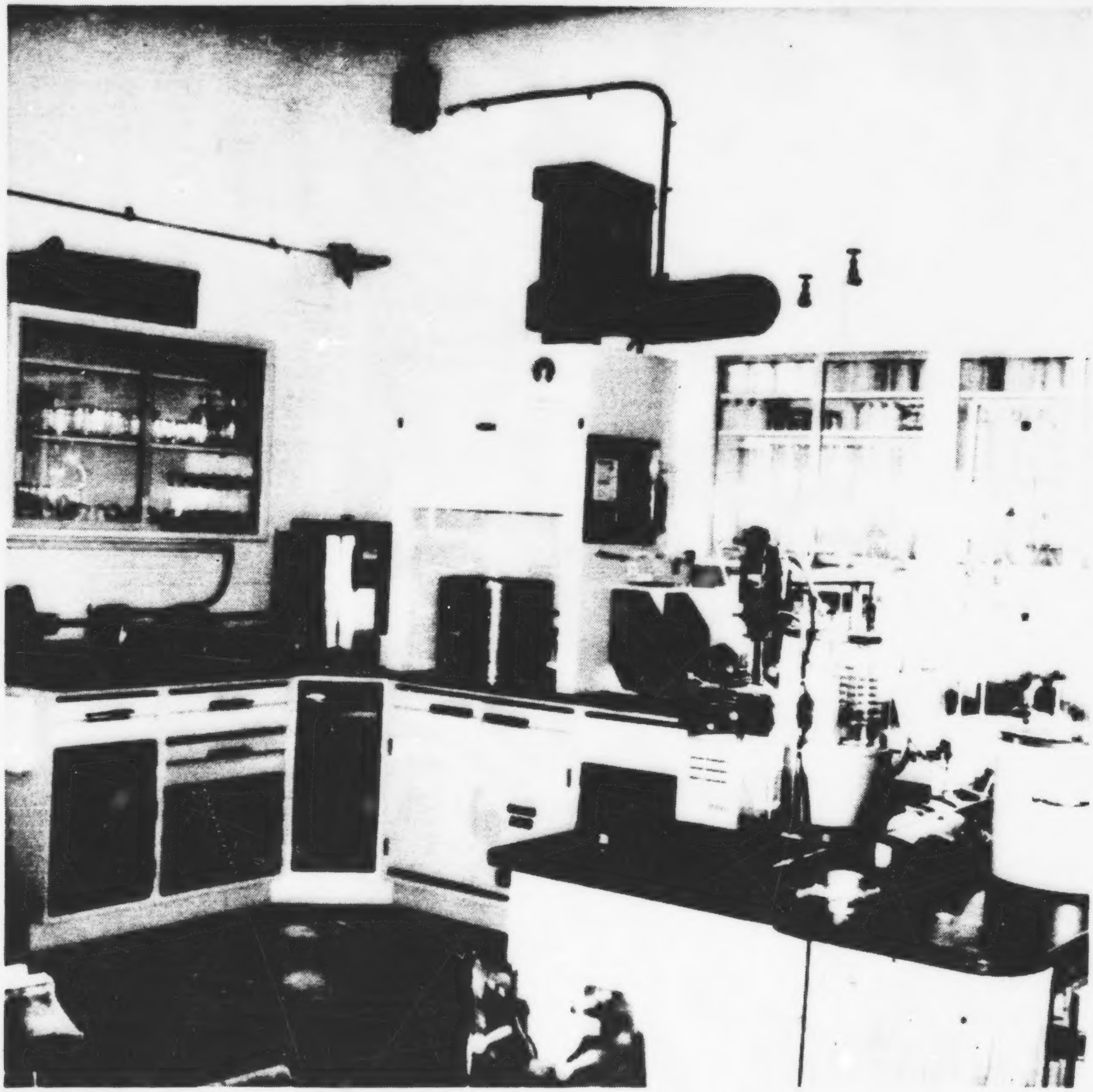
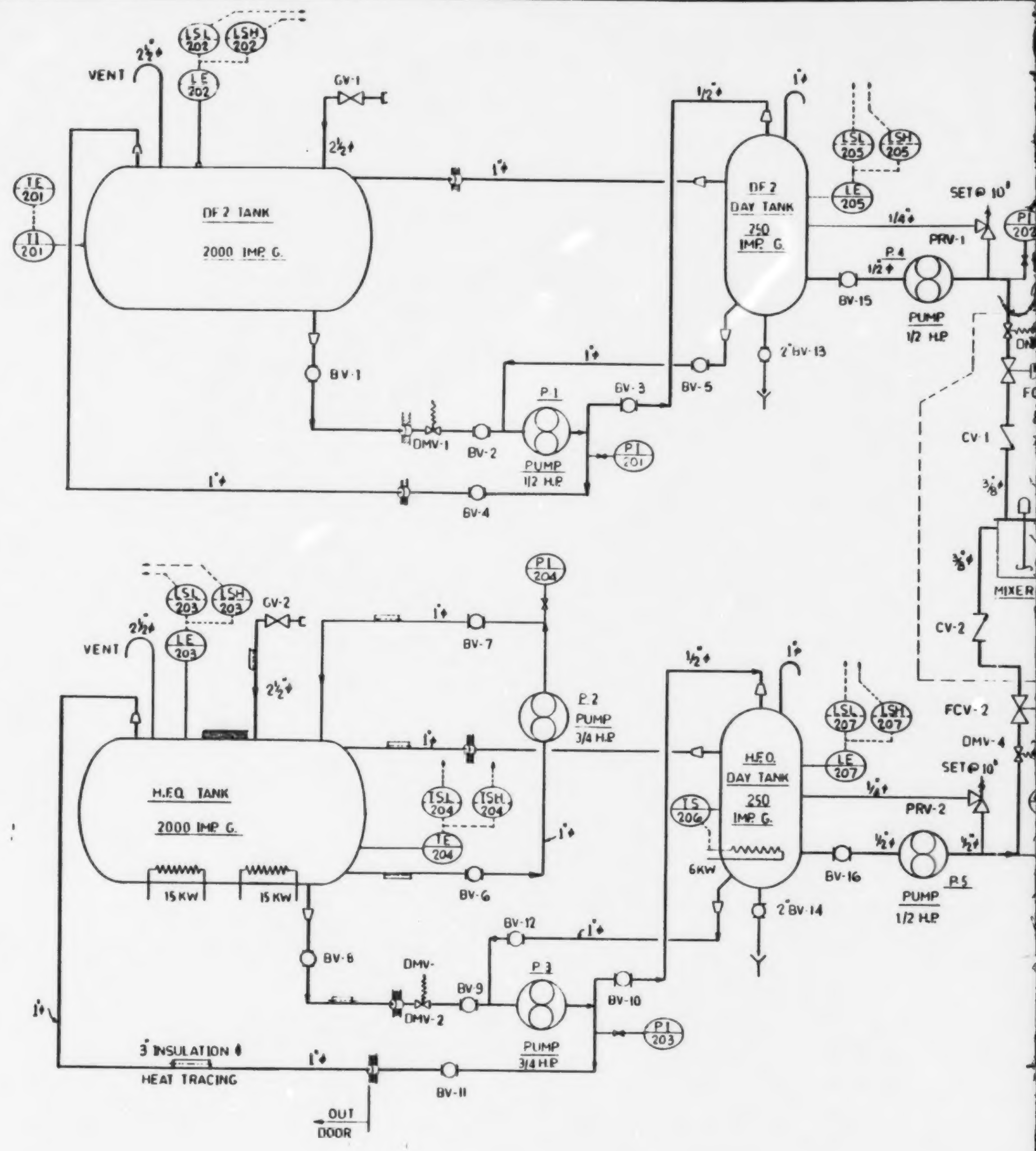


FIGURE 1 — CHEMICAL LABORATORY
(FUELS AND LUBRICANTS)


8
7
6
5
D
C
B
VENT
2½"φ
LSL 202
LSH 202
LE 202
GV-1
2½"φ
TE 201
TI 201
DF 2 TANK
2000 IMP. G.
1"φ
1/2"φ
1"φ
DF 2
DAY TANK
250
IMP. G.
LSL 205
LSH 205
LE 205
SET@ 10"
PI 202
1/4"φ
PRV-1
P.4
1/2"φ
BV-15
PUMP
1/2 H.P.
BV-1
1"φ
BV-3
BV-5
2" BV-13
DMV-1
BV-2
P.1
PUMP
1/2 H.P.
PI 201
1"φ
BV-4
CV-1
3/8"φ
3/8"φ
MIXER
CV-2
FCV-2
DMV-4
SET@ 10"
PI 204
LSL 203
LSH 203
GV-2
2½"φ
VENT
LE 203
2½"φ
1"φ
BV-7
P.2
PUMP
3/4 H.P.
1/2"φ
1"φ
LSL 207
LSH 207
LE 207
1"φ
H.F.O. TANK
2000 IMP. G.
TSL 204
TSH 204
TE 204
1"φ
H.F.O.
DAY TANK
250
IMP. G.
1/4"φ
PRV-2
TS 206
6KW
BV-16
1/2"φ
1/2"φ
PUMP
P.5
1/2 H.P.
2" BV-14
15 KW
15 KW
BV-6
BV-12
1"φ
BV-8
DMV-
BV-9
DMV-2
P.3
PUMP
3/4 H.P.
BV-10
PI 203
1"φ
3" INSULATION φ
HEAT TRACING
1"φ
BV-11
OUT
DOOR

PUMP SPEC.

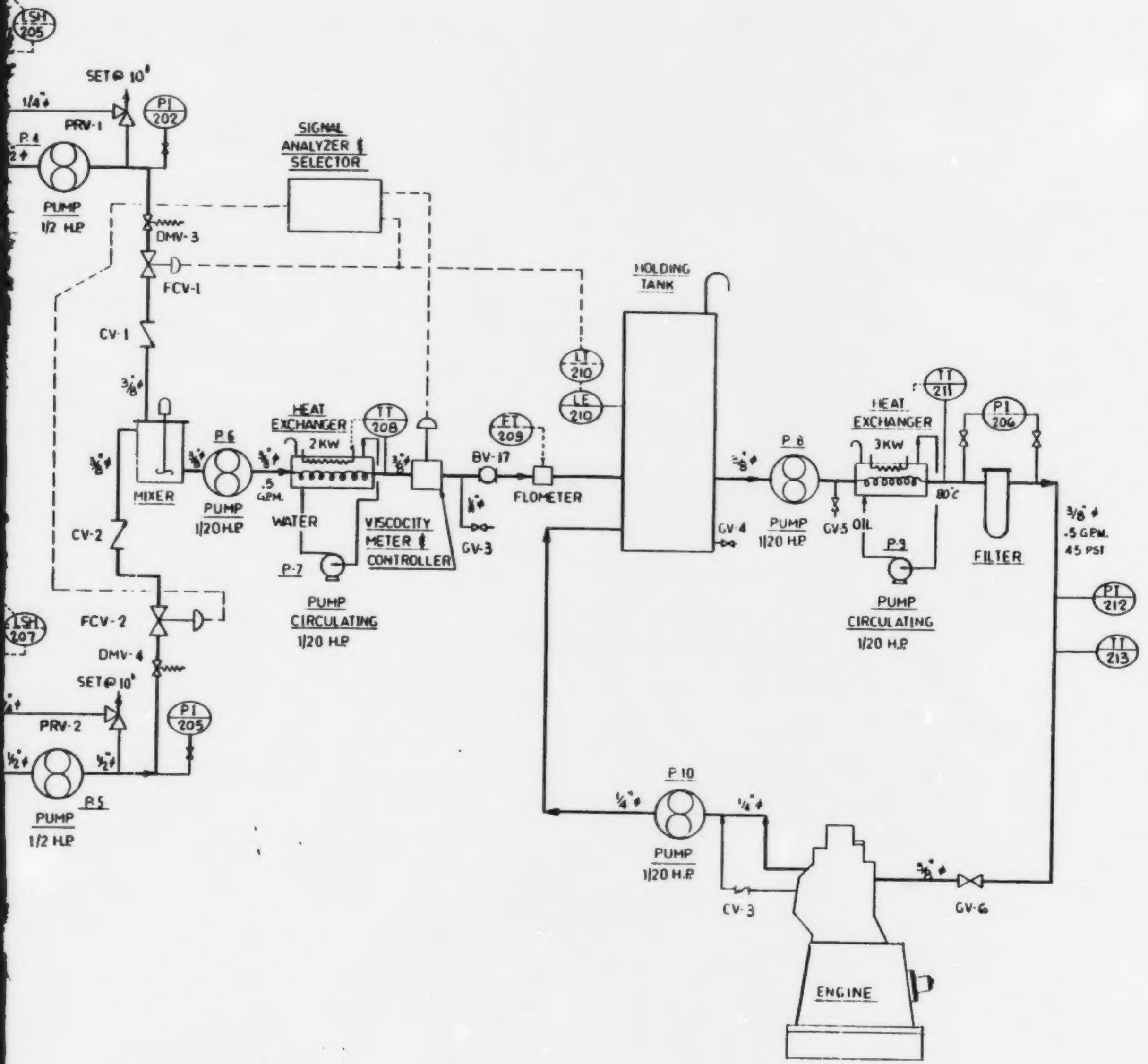
PUMP NO.→	P.1	P.2, P.3	P.4	P.5	P.6	P.7	P.8	P.9	P.10
GPM / LPM	5 / 19	5 / 19	5 / 19	5 / 19	0.5 / 1.9	1 / 3.8	0.5 / 1.9	1 / 3.8	0.6 / 2.3
PSI / KPa	10 / 69	10 / 69	10 / 69	10 / 69	10 / 69	3 / 20.7	55 / 379	3 / 20.7	3 / 20.7
TEMP °C	15	25	22	37	35	82	80	149	30

A

Rev.	Zone	Description	Init	Rev.	Zone	Description	Init	Rev.	Zone	Description	Init	Rev.	Zone

K-E 8 7 6 5

Zone	Repère / Item	(MA) P/N · P/S (CA) 3 · 14 18 · 29 Pièce n° / Part No.	P/N (MA) 001 Nom pièce / Part name	P/N (MA) 047 Matière / Raw Mat'l	P/N (MA) 082 Description	Masse Mass	P/S (CA) 003 Qté	P/N (MA) 063 U / M	P/N (MA) 037 Approv.


LSH 205
SET @ 10#
1/4"ϕ
PRV-1
PI 202
P.4
2"ϕ
PUMP 1/2 H.P.
SIGNAL ANALYZER & SELECTOR
DMV-3
FCV-1
CV-1
3/8"ϕ
HOLDING TANK
LT 210
LE 210
MIXER
P.6
PUMP 1/20 H.P.
3/8"ϕ
.5 G.P.M.
HEAT EXCHANGER
2 KW
TT 208
WATER
VISCOCITY METER & CONTROLLER
P-7
PUMP CIRCULATING 1/20 H.P.
FT 209
BV-17
FLOMETER
GV-3
GV-4
P.8
PUMP 1/20 H.P.
GV.5
HEAT EXCHANGER
3 KW
OIL
TT 211
80°C
PI 206
FILTER
P.9
PUMP CIRCULATING 1/20 H.P.
3/8"ϕ
.5 G.P.M.
45 PSI
PI 212
TT 213
CV-2
LSH 207
FCV-2
DMV-4
SET @ 10#
PRV-2
PI 205
1/2"ϕ
P.5
PUMP 1/2 H.P.
P.10
1/4"ϕ
PUMP 1/20 H.P.
CV-3
GV-6
ENGINE

VERIFICATEUR
C. GOURAND
86.11.17

Dessinateur H. Amin
Date 86.11.04
ING.
Date 86.11.07
Ch. groupe
Date 86.11.20
DIR.
Date

PROJECTION

TOLÉRANCE ET FINI DE SURFACE
SAUF INDICATION CONTRAIRE

MÉTRIQUE	000	± 0.5	
	000.0	± 0.05	
	000.00	± 0.005	
IMPÉRIAL	0 - 10"		10"+
FRAC. (MACH.)	± 1/32		± 1/16
DÉCIMAL	± .005		± .010
FRAC. (BRUT)	± 1/16		± 1/8

ANGLES ± 1/2° CHANFREIN ± 2°
ÉBARBER 1/64" / 0.4mm MAX
FINI DE SURFACE 125 mu in / VV

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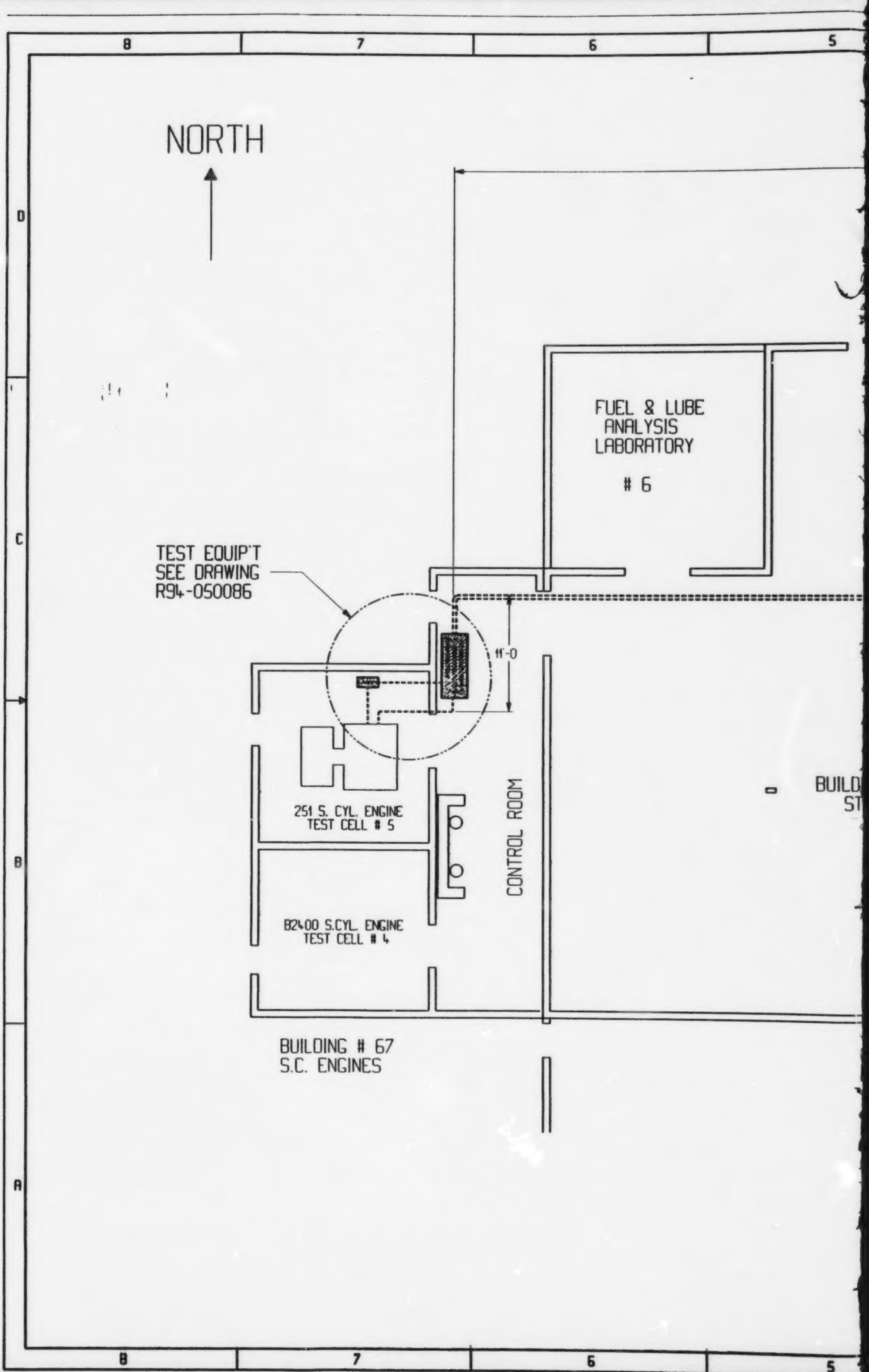
N° référence
N° ensemble / Assembly No. R94-050071, -050086
N° modèle A1
N° commande / Sales Order No.
Éch. / Sc. –

Bombardier Inc.
Division des produits ferroviaires et diesel
Rail and Diesel Products Division
Montreal, Quebec, Canada

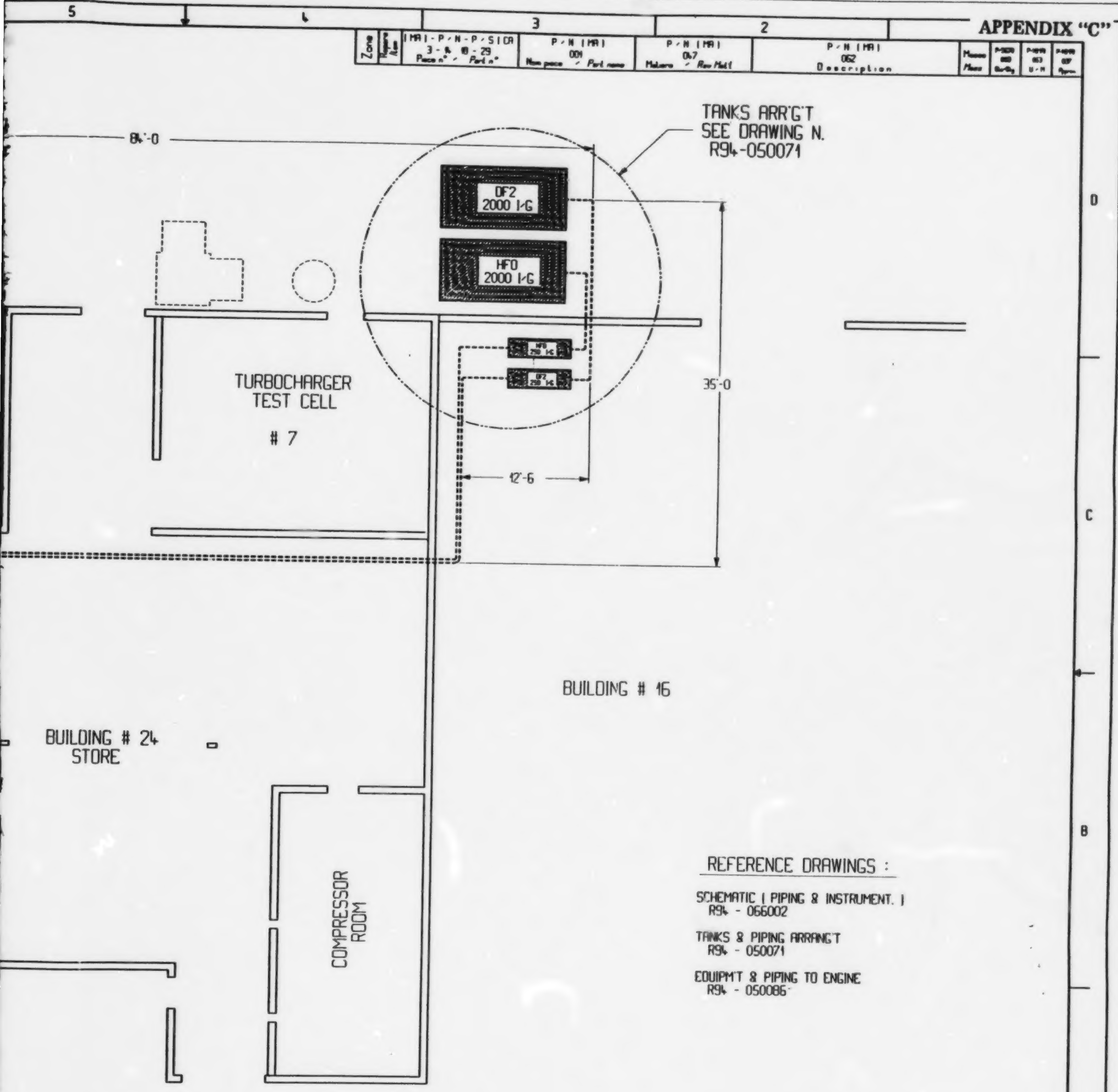
Objet / Subject
FLOW & INSTRUMENT DIAGRAM
pour / for FUEL BLENDING SYSTEM

Folio 1/1
Plan N° / Drawing No. R94 - 066002
Révision –

FIGURE 2


8
7
6
5
D
C
B
A
NORTH
FUEL & LUBE
ANALYSIS
LABORATORY
# 6
TEST EQUIP'T
SEE DRAWING
R94-050086
11'-0
CONTROL ROOM
251 S. CYL. ENGINE
TEST CELL # 5
B2400 S.CYL. ENGINE
TEST CELL # 4
BUILDING # 67
S.C. ENGINES
BUILD
ST

APPENDIX "C"


5
4
3
2
Zone
(MA)-P/N-P/SICA 3-4 10-29 Piece n° / Part n°
P/N (MA) 001 Nom piece / Part name
P/N (MA) 047 Matiere / Raw Mat'l
P/N (MA) 062 Description
TANKS ARR'G'T
SEE DRAWING N.
R94-050071
84'-0
DF2
2000 I-G
HFO
2000 I-G
HFO
250 I-G
DF2
250 I-G
35'-0
12'-6
TURBOCHARGER
TEST CELL
# 7
BUILDING # 16
BUILDING # 24
STORE
COMPRESSOR
ROOM
D
C
B
REFERENCE DRAWINGS :
SCHEMATIC (PIPING & INSTRUMENT.)
R94 - 066002
TANKS & PIPING ARRANG'T
R94 - 050071
EQUIPM'T & PIPING TO ENGINE
R94 - 050086

DIMENSIONS ARE IN INCHES

M.M'CHIRGUI
86N05
C. GOURAND
861120
R.E
D. [illegible]
861120

PROJECTION: ⊕ ⊲

TOLERANCE ET FINI DE SURFACE
SAUF INDICATION CONTRAIRE
DEC.(MACH.) 0.00 = +/- 0.03
000.0 = +/- 0.02
000.00 = +/- 0.01
000.000 = +/- 0.006
DEC.(BRUT.) +/- .06
ANGLES +/- 1/4 DEG. CHANFREIN +/- 2 DEG.
EBARBER 1/64
FINI DE SURFACE 125 MU IN.

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SEE NOTE

S.C.ENGINE

A1

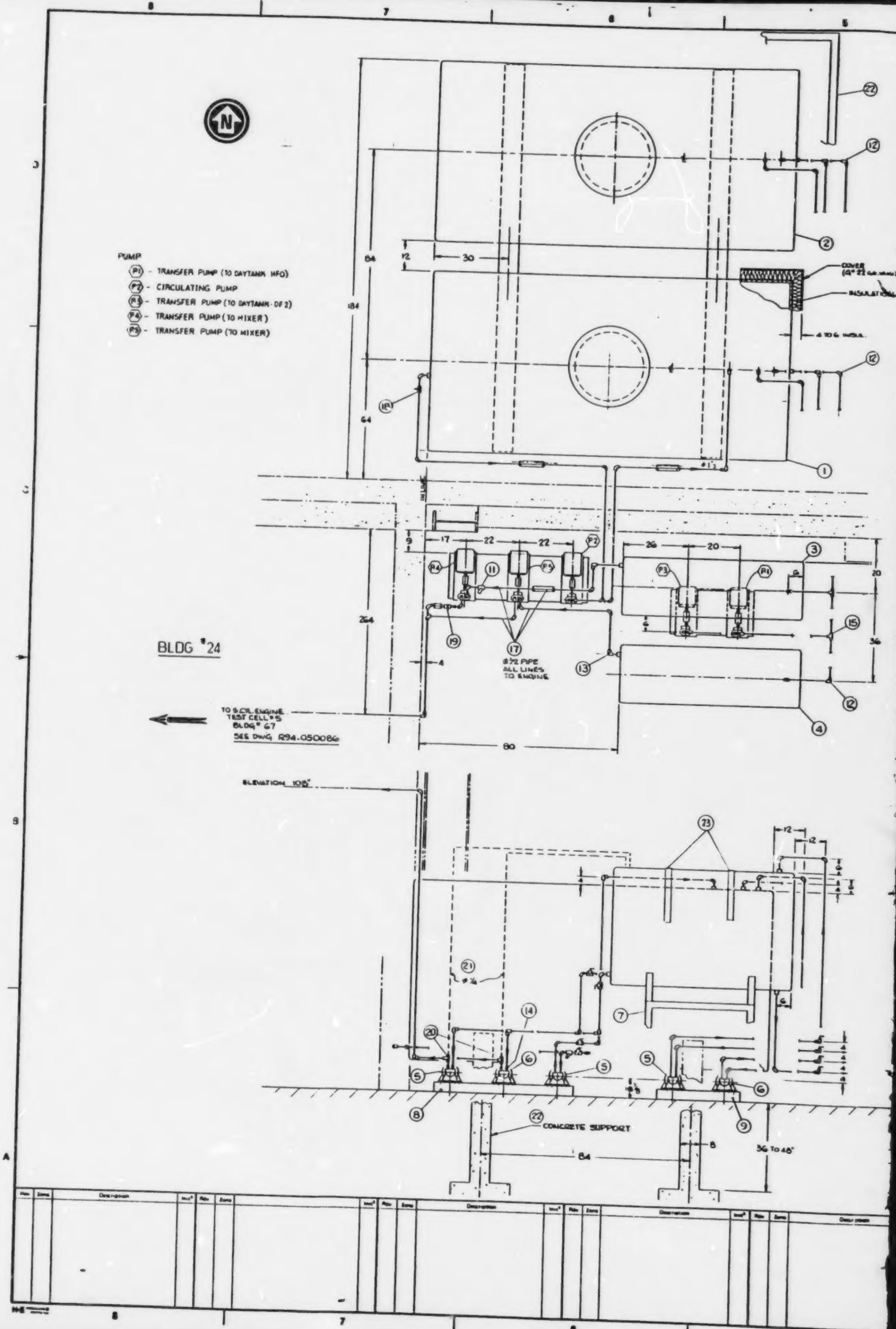
3/16-F

BOMBARDIER INC.
DIVISION DES PRODUITS FERROVIAIRES ET DIESEL
RAIL AND DIESEL PRODUCTS DIVISION
MONTREAL, QUEBEC, CANADA

OUTLINE
FUEL BLENDING SYSTEM

R94-050087

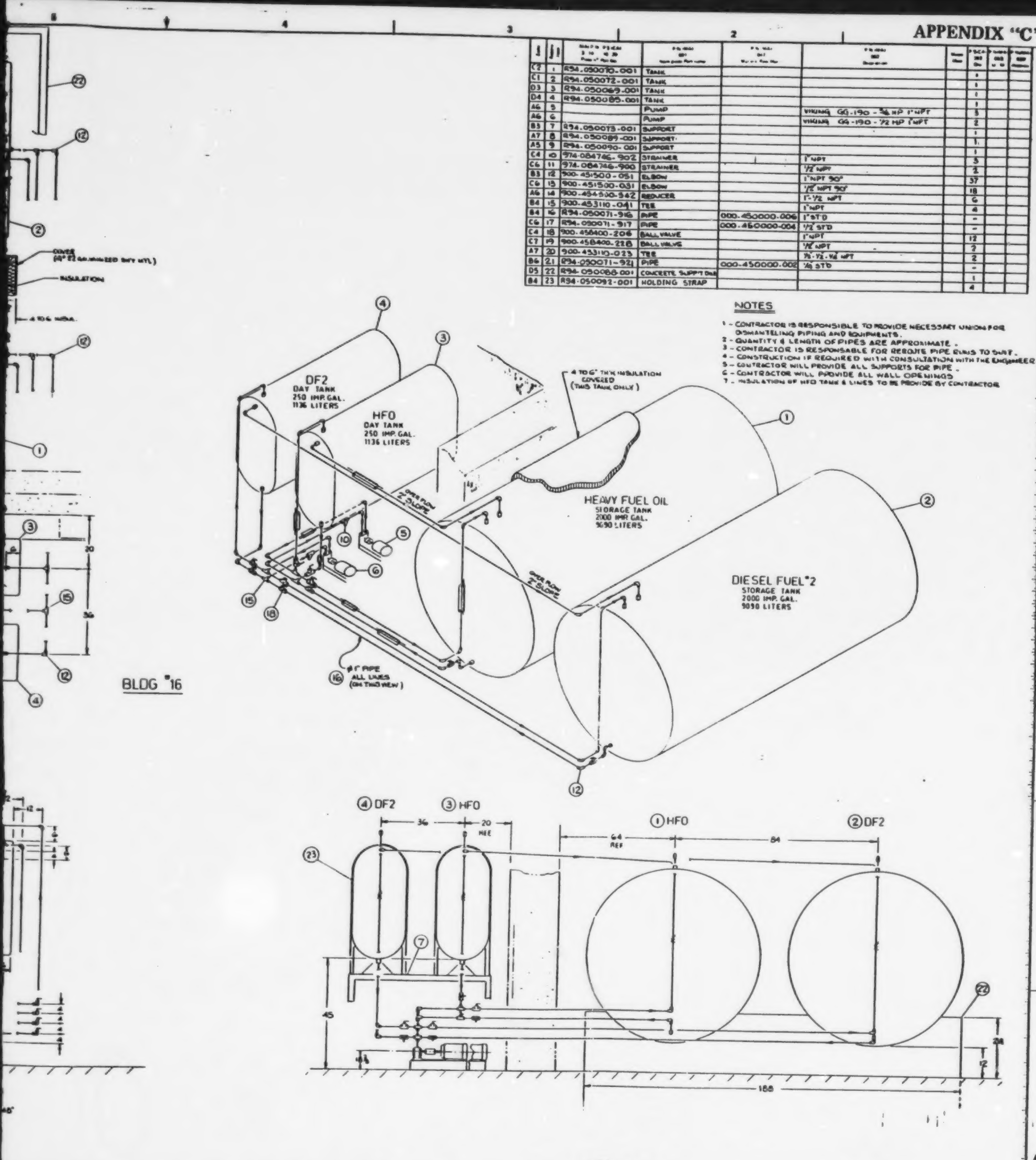
FIGURE 3


8
7
6
5
D
C
B
A
N
PUMP
P1 - TRANSFER PUMP (TO DAYTANK HFO)
P2 - CIRCULATING PUMP
P3 - TRANSFER PUMP (TO DAYTANK - DF 2)
P4 - TRANSFER PUMP (TO MIXER)
P5 - TRANSFER PUMP (TO MIXER)
BLDG #24
TO 6 CYL. ENGINE
TEST CELL #5
BLDG # 67
SEE DWG R94-050086
ELEVATION 108"
COVER
INSULATION
4 TO 6 INSUL.
Ø 1/2 PIPE
ALL LINES
TO ENGINE
CONCRETE SUPPORT
36 TO 48"
184
84
64
12
30
17
22
22
26
20
20
36
9
4
80
254
84
8
12
12
6
① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨ ⑪ ⑫ ⑬ ⑭ ⑮ ⑰ ⑱ ⑲ ⑳ ㉑ ㉒ ㉓
Ø 1/4
Rev
Zone
Description
Rev
Zone

C2	1	R94.050070-001	TANK				1		
C1	2	R94.050072-001	TANK				1		
D3	3	R94.050069-001	TANK				1		
D4	4	R94.050085-001	TANK				1		
A6	5		PUMP		VIKING GG-190 - ¾ HP 1" NPT		3		
A6	6		PUMP		VIKING GG-190 - ½ HP 1" NPT		2		
B3	7	R94.050073-001	SUPPORT				1		
A7	8	R94.050089-001	SUPPORT				1		
A5	9	R94.050090-001	SUPPORT				1		
C4	10	974-084746-902	STRAINER		1" NPT		3		
C6	11	974-084746-900	STRAINER		½" NPT		2		
B3	12	900-451500-051	ELBOW		1" NPT 90°		37		
C6	13	900-451500-031	ELBOW		½" NPT 90°		18		
A6	14	900-454500-542	REDUCER		1"-½" NPT		6		
B4	15	900-453110-041	TEE		1" NPT		4		
B4	16	R94-050071-916	PIPE	000.450000.006	1" STD		-		
C6	17	R94-050071-917	PIPE	000.450000-004	½" STD		-		
C4	18	900-458400-206	BALL VALVE		1" NPT		12		
C7	19	900-458400-228	BALL VALVE		½" NPT		7		
A7	20	900-453110-023	TEE		½"-½"-¼" NPT		2		
B6	21	R94-050071-921	PIPE	000-450000.002	¼" STD		-		
D5	22	R94-050088-001	CONCRETE SUPP'T DWG				1		
B4	23	R94-050092-001	HOLDING STRAP				4		

NOTES

1 - CONTRACTOR IS RESPONSIBLE TO PROVIDE NECESSARY UNION FOR DISMANTELING PIPING AND EQUIPMENTS.
2 - QUANTITY & LENGTH OF PIPES ARE APPROXIMATE.
3 - CONTRACTOR IS RESPONSABLE FOR REROUTE PIPE RUNS TO SUIT.
4 - CONSTRUCTION IF REQUIRED WITH CONSULTATION WITH THE ENGINEER.
5 - CONTRACTOR WILL PROVIDE ALL SUPPORTS FOR PIPE.
6 - CONTRACTOR WILL PROVIDE ALL WALL OPENINGS
7 - INSULATION OF HFO TANK & LINES TO BE PROVIDE BY CONTRACTOR


DF2
DAY TANK
250 IMP. GAL.
1136 LITERS
HFO
DAY TANK
250 IMP. GAL.
1136 LITERS
4 TO 6" THK INSULATION COVERED (THIS TANK ONLY)
HEAVY FUEL OIL
STORAGE TANK
2000 IMP. GAL.
9090 LITERS
DIESEL FUEL #2
STORAGE TANK
2000 IMP. GAL.
9090 LITERS
OVER FLOW 2" SLOPE
OVER FLOW 2" SLOPE
1" PIPE ALL LINES (ON THIS VIEW)
BLDG #16
COVER (16" GA GALVANIZED SHT MTL)
INSULATION
4 TO 6 INSUL.
④ DF2
③ HFO
① HFO
② DF2
36
20
64 REF
84
188
45
24
12
①
②
③
④
⑤
⑥
⑦
⑩
⑫
⑮
⑯
⑱
㉒
㉓

Bombardier Inc.
Division des produits ferroviaires et diesel
Rail and Diesel Products Division
Montreal Quebec Canada

EQUIP'T & PIPING ARRG'T
FUEL BLENDING SYSTEM

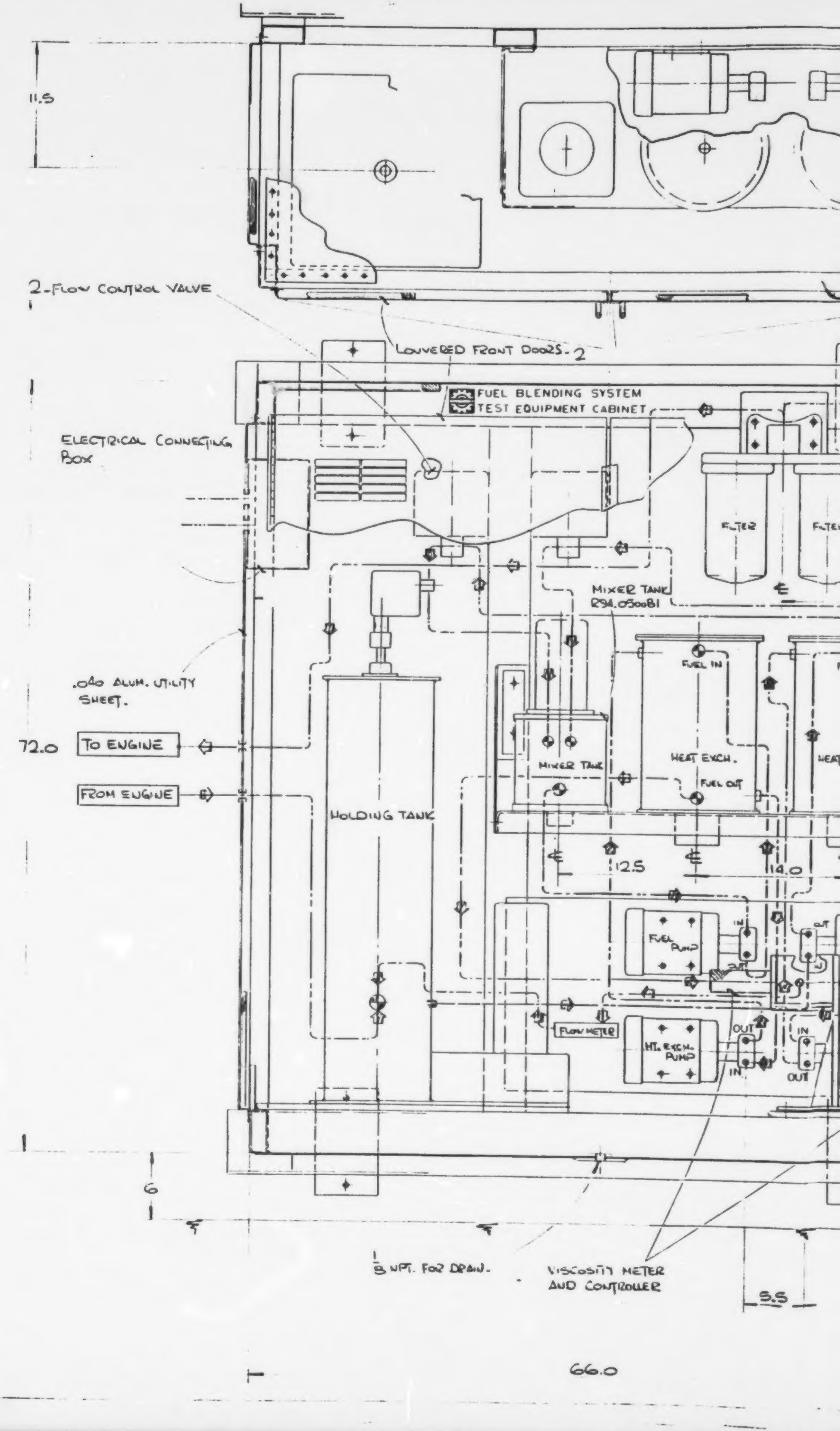
R94-050087

AO

R94-050071

861103
861117
861120

FIGURE 4


11.5
2-FLOW CONTROL VALVE
LOUVERED FRONT DOORS. 2
FUEL BLENDING SYSTEM
TEST EQUIPMENT CABINET
ELECTRICAL CONNECTING BOX
FILTER
FILTE
MIXER TANK
R94.050081
FUEL IN
.040 ALUM. UTILITY SHEET.
72.0
TO ENGINE
FROM ENGINE
HOLDING TANK
MIXER TANK
HEAT EXCH.
FUEL OUT
HEAT
12.5
14.0
FUEL PUMP
IN
OUT
FLOW METER
HT. EXCH. PUMP
OUT
IN
IN
OUT
6
1/8 NPT. FOR DRAIN.
VISCOSITY METER AND CONTROLLER
5.5
66.0

APPENDIX "C"

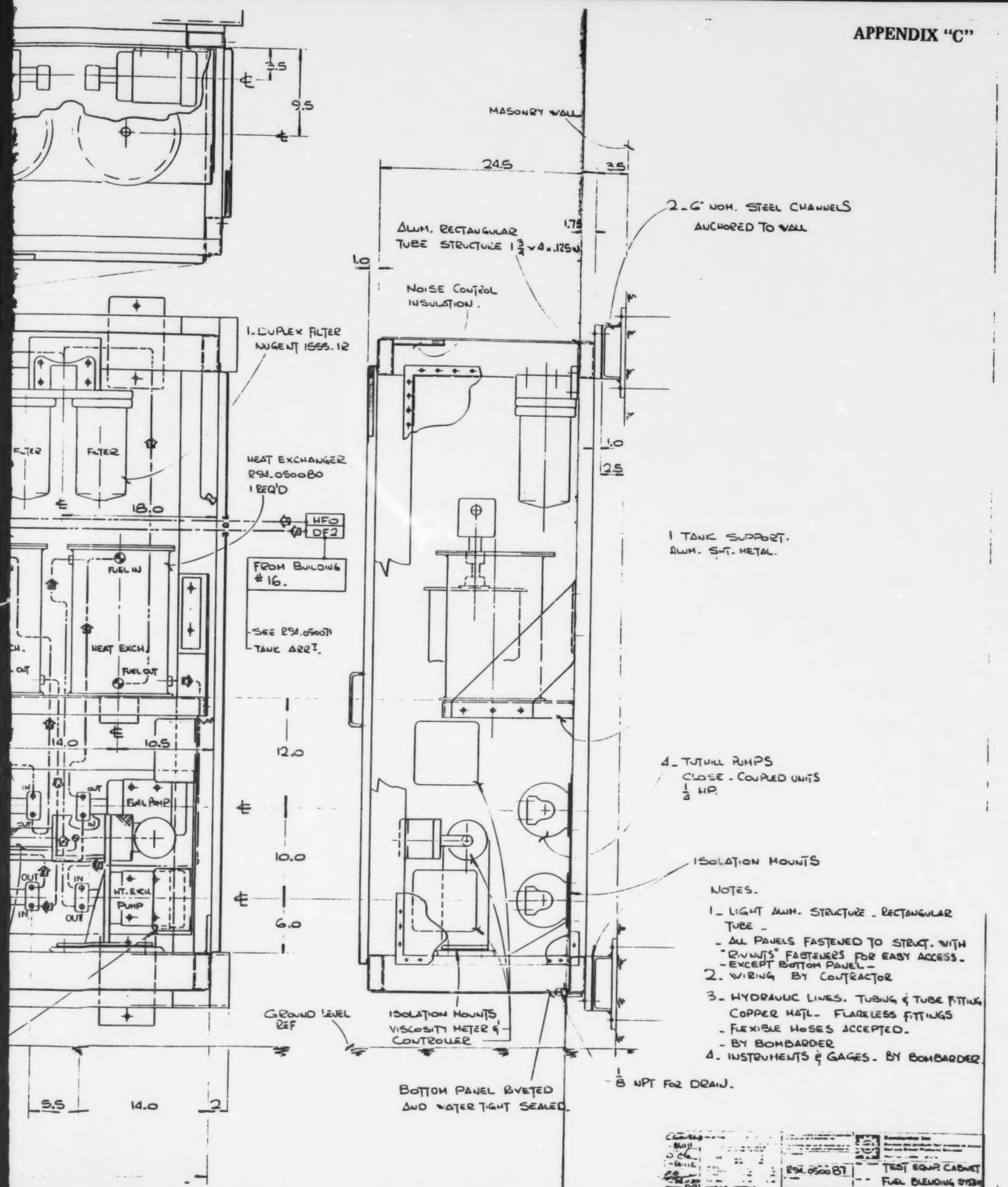

3.5
9.5
MASONRY WALL
24.5
3.5
2 - 6" NOM. STEEL CHANNELS
ANCHORED TO WALL
ALUM. RECTANGULAR
TUBE STRUCTURE 1 3/4 × 4 × .125W
1.75
1.0
NOISE CONTROL
INSULATION.
1. DUPLEX FILTER
NUGENT 1555.12
FILTER
FILTER
HEAT EXCHANGER
R94.050080
1 REQ'D
18.0
1.0
2.5
HFO
DF2
FROM BUILDING
#16.
FUEL IN
HEAT EXCH.
FUEL OUT
SEE R94.050071
TANK ARR'T.
1 TANK SUPPORT.
ALUM. SHT. METAL.
14.0
10.5
12.0
IN
OUT
FUEL PUMP
10.0
OUT
IN
HT. EXCH.
PUMP
6.0
4 - TUTHILL PUMPS
CLOSE - COUPLED UNITS
1/4 HP.
ISOLATION MOUNTS
NOTES.
1 - LIGHT ALUM. STRUCTURE - RECTANGULAR
TUBE -
- ALL PANELS FASTENED TO STRUCT. WITH
"RIVNUTS" FASTENERS FOR EASY ACCESS.
- EXCEPT BOTTOM PANEL -
2. WIRING BY CONTRACTOR
3 - HYDRAULIC LINES. TUBING & TUBE FITTING
COPPER MAT'L. FLARELESS FITTINGS
- FLEXIBLE HOSES ACCEPTED.
- BY BOMBARDER
4. INSTRUMENTS & GAGES. BY BOMBARDER.
GROUND LEVEL
REF
ISOLATION MOUNTS
VISCOSITY METER &
CONTROLLER
BOTTOM PANEL RIVETED
AND WATER TIGHT SEALED.
1/8 NPT FOR DRAIN.
5.5
14.0
2
R94.050087
TEST EQUIP. CABINET
FUEL BLENDING SYSTEM
R94.050086

FIGURE 5

Bombardier Inc.
Rail and Diesel Products Division
Montréal, Canada

Alco Power Inc.
Auburn, N.Y.,
U.S.A.

APPENDIX "C"

FIGURE 6

LUBRICATING OIL

INTRODUCTION

Development of high output diesel engines and the difficulty in obtaining distillate fuels with sulphur levels below 1%, adds increasing importance to the role of lubricating oils for properly protecting the dynamic components of the engine.

The oil industry, in keeping pace with these developments has developed or can develop lubricants which satisfactorily meet today's requirements.

The recommendations included in this Maintenance Instruction are offered as a guide to our customers, in selection and maintenance of engine lubricating oil.

OIL SPECIFICATION AND EVALUATION PROCEDURE

Unless the lubricant has earlier been successfully used on Bombardier manufactured engines, selection and evaluation of a suitable heavy duty lubricant should be carried out as suggested hereunder, before a lubricant is considered suitable.

Oil Supplier

A reliable oil supplier capable of making product recommendations, commensurate with Bombardier specifications and specific environmental influences, as well as having ability to furnish lubricants on a consistent quality level, should be consulted.

Oil Specification

Only an SAE 40 additive type lubricant conforming at least to API "CD" with adequate Alkalanity, (properties of a typical oil are listed below) and having been qualified through satisfactory field evaluation tests, as suggested in this M.I., should be used on Bombardier engines.

Property	Limits New Oil
Viscosity:	
SUS at 98.9°C (210°F)	72 - 85
CSt at 98.9°C (210°F)	13.5 - 16.8
SUS at 37.8°C (100°F)	700 - 1100
CSt at 37.8°C (100°F)	151 - 237.5
Viscosity Index	60 - 100
Flash Point °C	216
Viscosity:	
Pour Point °C	4.5 max.
Total Base No.	7 to 10 (if sulphur content of fuel is 0.5% to 0.7%) 10 to 13 (if sulphur content of fuel is 0.7% to 1%)

NOTE: Bombardier should be consulted for lube oil requirements if the sulphur content of fuel oil is above 1%.

Field Evaluation

Oils meeting the above specification are considered suitable for a field test. The field test should be conducted on a minimum of two Bombardier engines. The test duration should not be less than one year. The test engines should be subjected to normal service and maintenance schedule.

Data, in respect of physical and dimensional checks of the key components as listed below, should be collected before and on completion of the field test.

1. Cylinder Liner Diameter (Inside) - Fully Cleaned
    a. Location of top ring travel
    b. 6" from location (1)
    c. At bottom liner seat location

    Diameters to be measured at two right angle axes - along longitudinal and transverse directions.

2. Piston Dimensions
    a. Diameter (location crown top) - 2 axes - along axis of piston pin and at right angle
    b. Diameter (location crown bottom) - 2 axes - along axis of piston pin and at right angle
    c. Diameter (location below pin) - 2 axes - along axis of piston pin and at right angle
    d. Diameter piston pin hole - 2 locations
    e. Ring groove depth - all five grooves
    f. Piston pin diameter - 3 locations

3. Piston Rings
    a. Ring gaps - Use a new liner for measureing gap - all five rings
    b. Ring depth - all five rings

Data subject to change without notice.

4. Dimensions of:

   a. Valve guides inside diameter
   b. Valve lever shaft and bushing diameters
   c. Fuel pump lever bushing inside diameter
   d. Fuel pump roller pin diameter

5. Crankpin Diameters (All pins)

6. Visually observe and record conditions of:

   a. Small end bushings)
   b. Big end bearings)
   c. Main bearings)
   d. Camshaft lobes & rollers) Take photographs
   e. Valves and seats)
   f. Turbocharger bearings)

7. Engine performance data for:

   a. Engine load
   b. Exhaust temperatures
   c. Lube oil pressures in the manifold
   d. Air manifold pressures
   e. Turbine inlet temperatures

The wear rate and physical condition data supplied by the customer/oil supplier will be evaluated by Bombardier.

After successful completion of the field test programme the oil will be considered satisfactory for use.

Oil formulation established and proven by the above programme should not be changed. Any change in the additives or revision of the formulation in any way must be evaluated by the above method before the oil is considered suitable for use.

NOTE: The above evaluation programme is a complete responsibility both financially and otherwise, of the oil supplier, and/or the user. Bombardier will assist in carrying out analysis of test data and act only in an advisory capacity.

Mixing of Lubricants

Bombardier's recommendation against mixing of oil types cannot be over-emphasized, however, if this becomes mandatory, following suggestions are made to assist in reducing the risk associated with this practice.

- The number of lubricating oils to be mixed must be restricted to three for a given area of operation.

- The lubricants considered for mixing should have same additive concentrate.

- After the lubricants have been selected, an equally proportioned mixture must be subjected to field evaluation test listed above, and results analysed by Bombardier before adopting this practice for the fleet operation.

MAINTENANCE/LUBRICANT CONTROL

Key to proper evaluation and control of used lubricants, for satisfactory engine performance lies in:

- Knowing the oil type, the engine and the service severity
- Developing histories of a series of tests
- Correlating analytical results with engine condition
- Watching for abrupt changes for normal used oil condition

See Table for recommended test, frequency, ASTM test method, limits and action for lubricating oil used on Bombardier engines.

FIGURE 6

RECOMMENDED TESTING AND LIMITS FOR USED OIL

TEST	RECOMMENDED FREQUENCY	ASTM TEST DESIGNATION	USED OIL LIMITS
Appearance & odor	Trip	No Numerical Limits - Interpreted by observer	
Crackle	Trip	No Numerical Limits - Interpreted by observer	
Blotter Spot Test	Trip	No Numerical Limits - Interpreted by observer	
Viscosity Increase at 100°C	Monthly	D 88 or D 445	± 20%
Viscosity Increase at 40°C	Trip	D 88 or D 445	± 30%
Viscosity Index	Monthly	D 567	
Pentane Insolubles	Monthly	D 893	3% max. (coagulated)
Benzene Insolubles	Monthly	D 893	Report
Fuel Dilution Vol. %	Trip	D 322	5% max.
Sulphated Ash Content	Monthly	D 874	6% of new value
Total Base No.	Monthly	D 2896	3 - for oils with TBN of 7 to 10 when new
Total Base No.	Monthly	D 2896	6 - for oils with TBN of 10 to 13 when new
PH	Monthly	D 664	5

TRACE ELEMENTS PPM MAX.

TEST	RECOMMENDED FREQUENCY	ASTM TEST DESIGNATION	USED OIL LIMITS	If results higher than limit inspect
Aluminium	Monthly	Spectrographic	5 PPM	Piston
Chromium	Monthly	Spectrographic	10 PPM	Liner & water leaks
Copper	Monthly	Spectrographic	20 PPM	Bushings
Iron	Monthly	Spectrographic	50 PPM	Rings and other ferrous parts
Lead	Monthly	Spectrographic	10 PPM	Main Conn. rod & turbo, lead bearing
Silicon	Monthly	Spectrographic	5 PPM	Air filters
Sodium	Monthly	Spectrographic	30 PPM	Water leaks (water treatment contains sodium)

NOTE: If any trace elements show a sudden or unexplained increase, this is sufficient reason to inspect engine components for unusual wear.

APPENDIX "C"

FIGURE 6

LIST OF LUBRICATING OILS KNOWN TO HAVE PERFORMED SATISFACTORILY ON 251 ENGINES

The inclusion of a product in this list does not imply approval or endorsement by Bombardier. It is published for the information of operators of 251 engines to assist them in obtaining satisfactory engine performance.

Supplier	Brand Name	TBN
BP Canada Ltd.	BP Energol 1C-RG40	6
BP Oil Company (USA)	BP Dieselube RR240	6
BP Trading Co. Ltd. (International)	BP Energol 1C-R1140	6
	BP Energol 1C-RT40	7
Gulf Oil Canada Ltd.	Ralube 950	
Gulf Oil (USA)	Gulf Oil 493	
Exxon (Imperial Oil Ltd., Canada)	Galena RD40	6.4
Exxon Corporation	Dion RDX	
Pemex (Mexico)	Dieselmex	
Shell Canada Ltd.	Tornus Oil 40	
Shell Oil Company and Affiliates	Caprinus T Oil 40	7
	Caprinus R Oil 40	10
	Tornus Oil 40	7
	Caprinus Oil 40	10
	Janus Oil 40	11
	Rotella T Oil 40	9
	Rotella TX Oil 40	9.5
Texaco Canada	DEO 1570	6.5
Texaco Inc. (USA and overseas)	2208 Taro 4-80	

FIGURE 7

FUEL OIL SPECIFICATIONS

This bulletin provides recommendations for fuel oil to provide efficient low maintenance operation of the engines, as well as economical procurement of the fuel.

The fuel shall conform to the following requirements (ASTM Test Methods).

Cetane Number	40 min.
Distillation Temperature (90% Point)	640°F max.
Flash Point	125°F min.
Water and Sediment	0.05% max.
Conradson Carbon Residue (10% Bottoms)	0.35% max.
Ash	0.01% max.
Viscosity SSU @ 100°F	32-45
Sulphur	1.8% max.
Copper Strip Corrosion	No. 3 max.

NOTES:

1. For cold weather operation, the cloud point and pour point shall be 10°F below the prevailing ambient temperature, except where fuel oil heating facilities are provided.

2. Low atmospheric temperatures, as well as engines operating at very high altitudes, may require the use of fuels with a higher cetane rating.

3. Gum content of the fuel shall be at a level consistent with satisfactory engine performance.

4. Fuel oil, lubricating oil and engine service are mutually interdependent. A marked change in any one of these variables should be accompanied by careful engine observations to determine the effect of the change on engine condition.

5. Fuels not meeting the above requirements in all respects shall only be used after testing has established their affect on engine operation and maintenance.

6. "Fuel Oil, Diesel, Marine", to military specification MIL-F-16884 meets the above requirements.

7. "Turbine Fuel", to grade JP-5 of military specification MIL-T-5624 is acceptable.

*8. Fuels meeting the above requirements in all respects except for the sulfur content may be suitable for use. If the sulfur content of the fuel is over 0.75%, care should be taken to ensure the use of a lubrication oil having a total base number (TBN) that is compatible with respect to the sulfur level of the fuel. For further information, consult Alco Power Inc., Technical Publications Department.

STANDBY SERVICE UNITS

Standby units have a particular problem in that a comparably large fuel supply is required, but little is used during the weekly exercising of the engines.

All fuel oil tends to degrade during extended storage. The degradation, in general, is of two types. The first is oxidation and polymerization resulting in the formation of soluble and insoluble gums. The gums in the fuel can ultimately result in exhaust valve sticking during the unloaded idling of the engine during exercising. The second is bacteria growth at the interface of the fuel and water in the storage tank, resulting in clumps of bacteria in the fuel. This bacterial growth will result in fuel filter plugging and has been known to cause fuel injection sticking.

Both of these degradation processes can be inhibited by the use of stability additives put into the fuel. The oxidation can be limited by certain proprietary anti-oxidants and dispersants, while the bacteria can be controlled by the use of biocides. However, fuels vary in their response to both the inhibitors, and testing will be required to determine the suitable dosage of the material. Also, it is known that the oxidation inhibitor cannot provide indefinite protection against the formation of the gums, and testing of the fuel would be required periodically to establish that the gums are within allowable limits. The use of the additives, particularly the biocide, may result in a conflict with environmental air regulations in some areas.

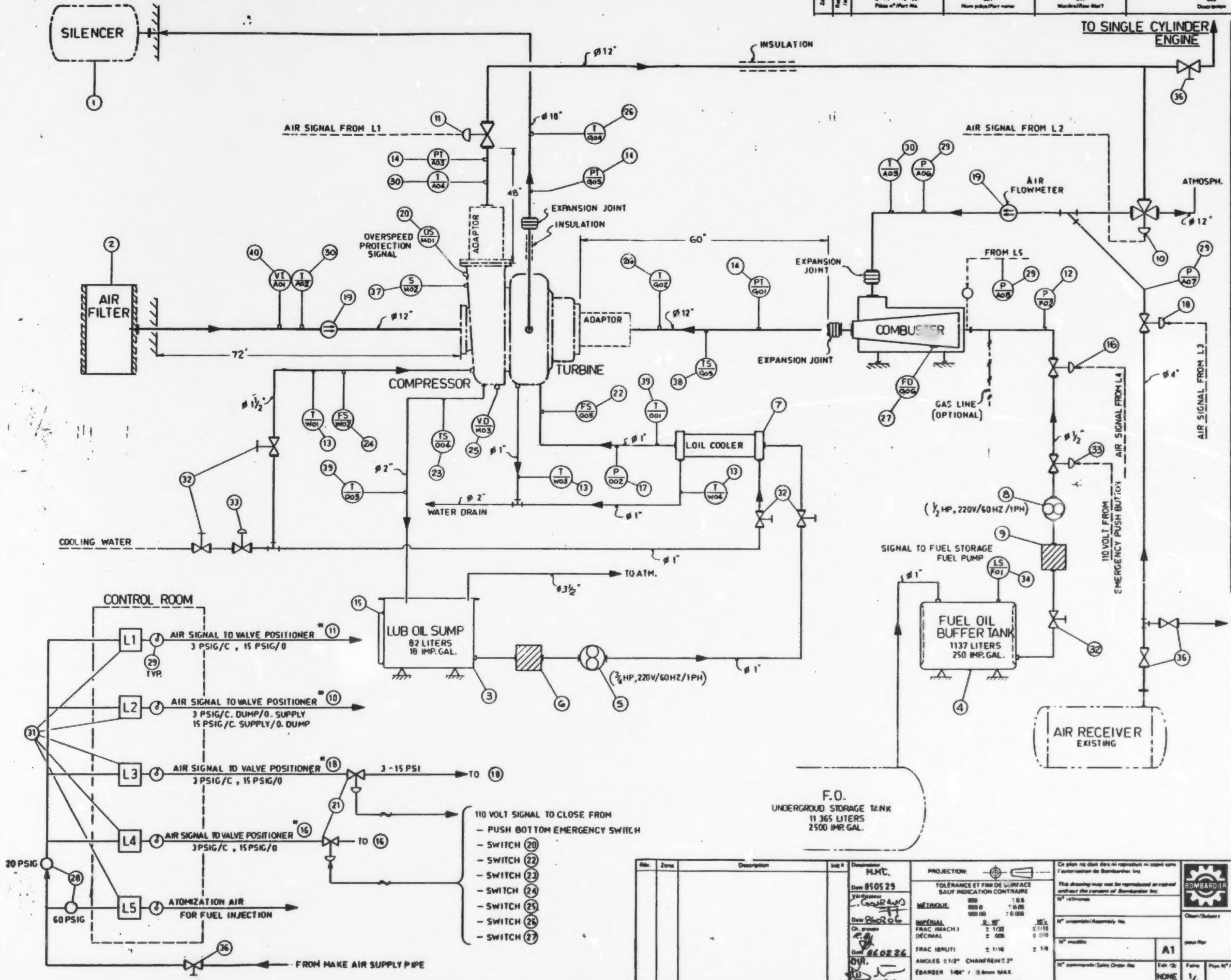
In view of the testing and difficulties involved in assuring proper stability of fuel oil with additives, the most satisfactory method for insuring good fuel at all times is to replace the fuel periodically. We recommend that arrangements be made with the fuel supplier to pump out the fuel at six month intervals and replace it with new fuel. The pumped out fuel can be used by the supplier in less critical applications or can be dumped into a bulk storage tank thereby diluting the contaminants. It is probable that this can be accomplished at less cost than trying to maintain the fuel in good condition by treatment.

APPENDIX "D"

TURBOCHARGER TEST CELL

Fig. 1 General circuit arrangement
Fig. 2 Turbocharger test cell general arrangement
Fig. 3 Main ducting - compressor discharge
Fig. 4 Combustor assembly
Fig. 5 Turbo - ducting
Fig. 6 Piping arrangement
Fig. 7 Pneumatic control
Fig. 8 Control desk

APPENDIX "D"


SILENCER
AIR FILTER
COMPRESSOR
TURBINE
ADAPTOR
COMBUSTER
INSULATION
EXPANSION JOINT
TO SINGLE CYLINDER ENGINE
ATMOSPH.
AIR SIGNAL FROM L1
AIR SIGNAL FROM L2
AIR SIGNAL FROM L3
AIR SIGNAL FROM L4
FROM L5
AIR FLOWMETER
OVERSPEED PROTECTION SIGNAL
GAS LINE (OPTIONAL)
110 VOLT FROM EMERGENCY PUSH BUTTON
Ø12"
Ø18"
Ø4"
Ø1½"
Ø2"
Ø1"
Ø3½"
48"
60"
72"
COOLING WATER
WATER DRAIN
TO ATM.
L.OIL COOLER
LUB OIL SUMP
82 LITERS
18 IMP. GAL.
(¾ HP, 220V/60HZ/1PH)
(½ HP, 220V/60HZ/1PH)
SIGNAL TO FUEL STORAGE FUEL PUMP
FUEL OIL BUFFER TANK
1137 LITERS
250 IMP. GAL.
AIR RECEIVER
EXISTING
TO CONTROL MAIN HEADER
F.O.
UNDERGROUD STORAGE TANK
11 365 LITERS
2500 IMP. GAL.
CONTROL ROOM
L1
AIR SIGNAL TO VALVE POSITIONER ⑪
3 PSIG/C , 15 PSIG/0
TYP.
L2
AIR SIGNAL TO VALVE POSITIONER ⑩
3 PSIG/C. DUMP/0. SUPPLY
15 PSIG/C. SUPPLY/0. DUMP
L3
AIR SIGNAL TO VALVE POSITIONER ⑱
3 PSIG/C , 15 PSIG/0
3 - 15 PSI
TO ⑱
L4
AIR SIGNAL TO VALVE POSITIONER ⑯
3 PSIG/C , 15 PSIG/0
TO ⑯
L5
ATOMIZATION AIR FOR FUEL INJECTION
110 VOLT SIGNAL TO CLOSE FROM
- PUSH BOTTOM EMERGENCY SWITCH
- SWITCH ⑳
- SWITCH ㉒
- SWITCH ㉓
- SWITCH ㉔
- SWITCH ㉕
- SWITCH ㉖
- SWITCH ㉗
20 PSIG
60 PSIG
FROM MAKE AIR SUPPLY PIPE
PT A03
T A04
PT A05
T G04
OS M01
S M02
VT A01
T A02
T G02
PT G01
TS G03
FD G06
T A05
P A06
P A08
P F02
P A07
T W01
FS W02
TS 004
VD M03
FS 005
T 001
T 003
T W03
P 002
T W04
LS F01

ITEM	DESCRIPTION
1	SILENCER
2	AIR FILTER
3	L.O. SUMP
4	F.O. TANK
5	L.O. PUMP
6	L.O. FILTER
7	L.O. COOLER
8	F.O. PUMP
9	F.O. FILTER
10	3 WAYS BUTTERFLY VALVE
11	BUTTERFLY VALVE
12	FUEL OIL PRESSURE GAUGE
13	WATER TEMP. TURBOCHARGER
14	AIR PRESSURE TRANSDUCER
15	LEVEL INDICATOR
16	F.O. SUPPLY MOD'G VALVE
17	LUB. OIL PRESSURE GAUGE
18	AIR MODULATING VALVE
19	AIR FLOWMETER
20	OVERSPEED DETECTOR
21	AIR SOLENOID VALVE 3 W.
22	L.O. FLOW SWITCH
23	HIGH OIL TEMP. SWITCH
24	COOLING WATER FLOW SWITCH
25	EXCESSIVE VIBRATION DETEC
26	GAS TEMP. THERMOCOUPLE
27	FLAME DETECTOR
28	AIR PRESSURE REGULATOR
29	AIR PRESSURE GAUGE
30	AIR TEMP. THERMOCOUPLE
31	VALVE POSIT. LOADERS REGE
32	MANUAL VALVE (LIQUID)
33	INDEPENDEND EMERGENCY SW.
34	LEVEL SWITCH
35	
36	MANUAL VALVE (AIR)
37	SPEED PICK UP
38	TURBINE INLET TEMP. SWITCH
39	LUB. OIL TEMPERATURE
40	VACUUM GAUGE

Dessinateur M.M.C.
Date 850529
Vérificateur C. Gourdes
Date 860206
Date 860226
DIR.
Date 860317

PROJECTION:

TOLÉRANCE ET FINI DE SURFACE SAUF INDICATION CONTRAIRE

FRAC (BRUT) ± 1/16 ± 1/8
ANGLES ± 1/2° CHANFREIN ± 2°
ÉBARBER 1/64" / 0.4mm MAX
FINI DE SURFACE 1.25 mu m / √√

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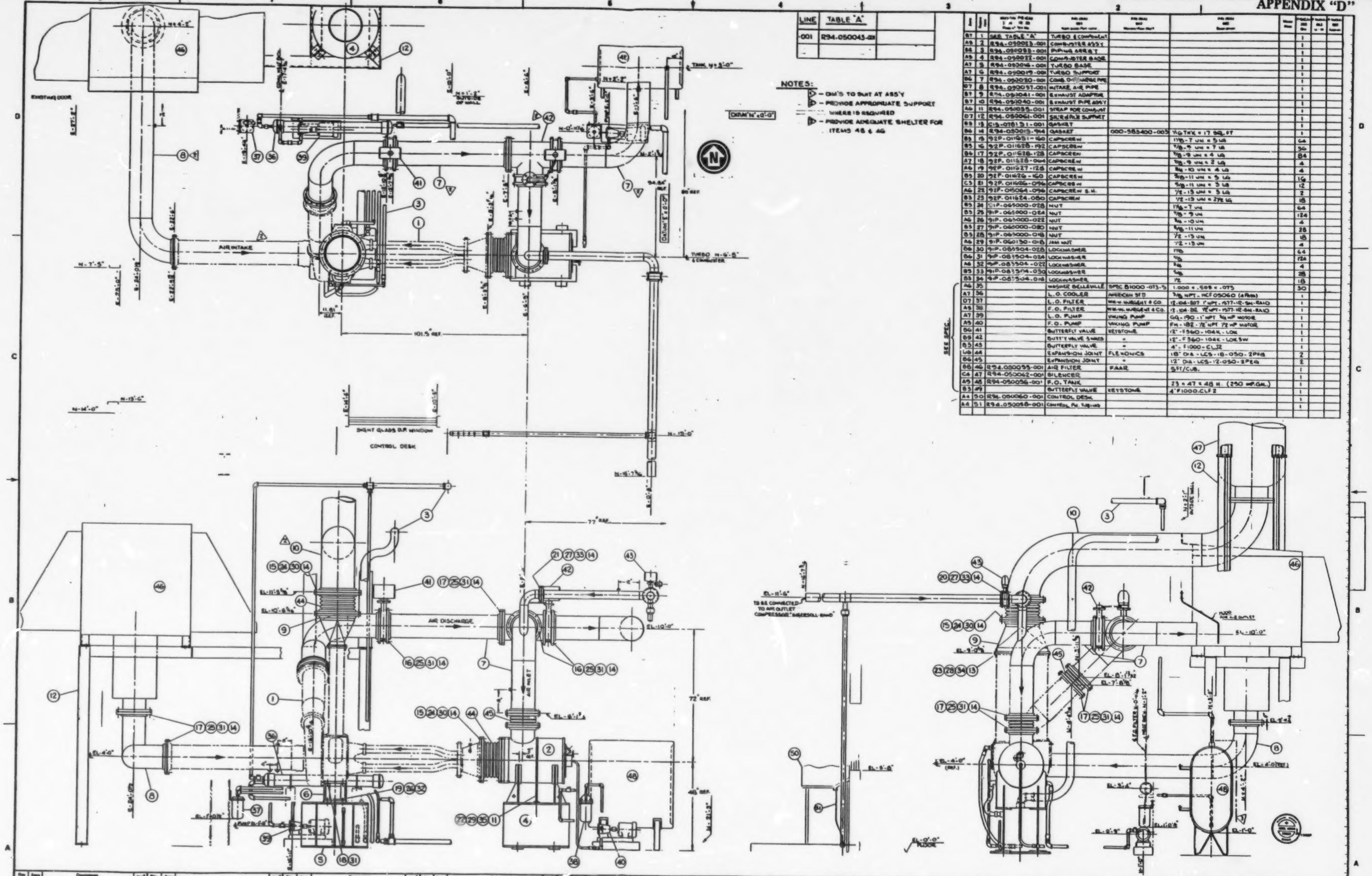
Bombardier Inc.
Division des produits ferroviaires et diesel
Rail and Diesel Products Division
Montreal, Québec, Canada

GENERAL CIRCUIT
TURBOCHARGER
TEST CELL FACILITY

A1
NONE
1/1
R94 -057001

FIGURE 1



LINE	TABLE "A"	
-001	R94-050043-01	

NOTES:

1 – DIM'S TO SUIT AT ASS'Y

2 – PROVIDE APPROPRIATE SUPPORT WHERE IS REQUIRED

3 – PROVIDE ADEQUATE SHELTER FOR ITEMS 48 & 46

B7	1	SEE TABLE "A"	TURBO & COMPONENT				1		
A9	2	R94-050023-001	COMBUSTER ASS'Y				1		
B8	3	R94-050053-001	PIPING ARR'G'T				1		
A9	4	R94-050022-001	COMBUSTER BASE				1		
A7	5	R94-050016-001	TURBO BASE				1		
A7	6	R94-050019-001	TURBO SUPPORT				1		
D6	7	R94-050020-001	COMB. DISCHARGE PIPE				1		
D7	8	R94-050037-001	INTAKE AIR PIPE				1		
B7	9	R94-051041-001	EXHAUST ADAPTOR				1		
B7	10	R94-051040-001	EXHAUST PIPE ASS'Y				1		
A6	11	R94-050035-001	STRAP FOR COMBUST				1		
D7	12	R94-050061-001	SIL'R & FLR SUPPORT				1		
B3	13	C15-078131-001	GASKET				1		
B6	14	R94-050019-904	GASKET	000-383400-003	1/16 THK × 17 SQ. FT		1		
B3	15	92P-011651-160	CAPSCREW		1 1/8-7 UN × 5 LG		64		
B5	16	92P-011628-192	CAPSCREW		7/8-9 UN × 7 LG		36		
B6	17	92P-011628-128	CAPSCREW		7/8-9 UN × 4 LG		84		
A7	18	92P-011628-064	CAPSCREW		7/8-9 UN × 2 LG		4		
A6	19	92P-011627-128	CAPSCREW		3/4-10 UN × 4 LG		4		
B5	20	92P-011626-160	CAPSCREW		5/8-11 UN × 5 LG		16		
C3	21	92P-011626-096	CAPSCREW		5/8-11 UN × 3 LG		12		
A6	22	92P-015064-096	CAPSCREW S.H.		1/2-13 UN × 3 LG		2		
B3	23	92P-011624-080	CAPSCREW		1/2-13 UN × 2 1/2 LG		18		
B3	24	91P-065000-028	NUT		1 1/8-7 UN		64		
B5	25	91P-065000-024	NUT		7/8-9 UN		124		
A6	26	91P-065000-022	NUT		3/4-10 UN		4		
B3	27	91P-065000-020	NUT		5/8-11 UN		28		
B3	28	91P-065000-018	NUT		1/2-13 UN		18		
A6	29	91P-060130-018	JAM NUT		1/2-13 UN		4		
B6	30	91P-083504-028	LOCKWASHER		1 1/8		64		
B6	31	91P-083504-024	LOCKWASHER		7/8		124		
A6	32	91P-083504-022	LOCKWASHER		3/4		4		
B3	33	91P-083504-030	LOCKWASHER		5/8		28		
B3	34	91P-083504-018	LOCKWASHER		1/2		18		
A6	35		WASHER BELLEVILLE	SPEC B1000-073-5	1.000 × .509 × .073		30		
A7	36		L.O. COOLER	AMERICAN STD	3/8 NPT - HCF 05060 (4 PASS)		1		
D7	37		L.O. FILTER	WM. W. NUGENT & CO	12.104-207 1" NPT - 1577-12-SM-RA10		1		
A9	38		F.O. FILTER	WM. W. NUGENT & CO.	12.104-22 1/2" NPT - 1577-12-SM-RA10		1		
A7	39		L.O. PUMP	VIKING PUMP	GG-190 - 1" NPT 3/4 HP MOTOR		1		
A9	40		F.O. PUMP	VIKING PUMP	FH-182 - 1/2" NPT 1/2 HP MOTOR		1		
B6	41		BUTTERFLY VALVE	KEYSTONE	12"-F360-104K-LOK		1		
B5	42		BUTT'F VALVE [illegible]	"	12"-F360-104K-LOK SW		1		
B3	43		BUTTERFLY VALVE	"	4"-F1000-CL32		1		
C6	44		EXPANSION JOINT	FLEXONICS	18" DIA - LCS-18-050-2PEG		2		
B6	45		EXPANSION JOINT	"	12" DIA - LCS-12-050-2PEG		2		
B8	46	R94-050055-001	AIR FILTER	FAAR	5FT/CUB.		1		
C4	47	R94-050062-001	SILENCER				1		
A9	48	R94-050056-001	F.O. TANK		23 × 47 × 48 H. (250 IMP. GAL.)		1		
B3	49		BUTTERFLY VALVE	KEYSTONE	4" F1000.CLF2		1		
A4	50	R94-050060-001	CONTROL DESK				1		
A4	51	R94-050058-001	CONTROL PN. TUBING				1		

SEE SPEC.

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Division des produits ferroviaires et diesel
Rail and Diesel Products Division
Montreal, Quebec, Canada

SEE ALSO - R94-050053

AO

GENERAL ARRANGEMENT

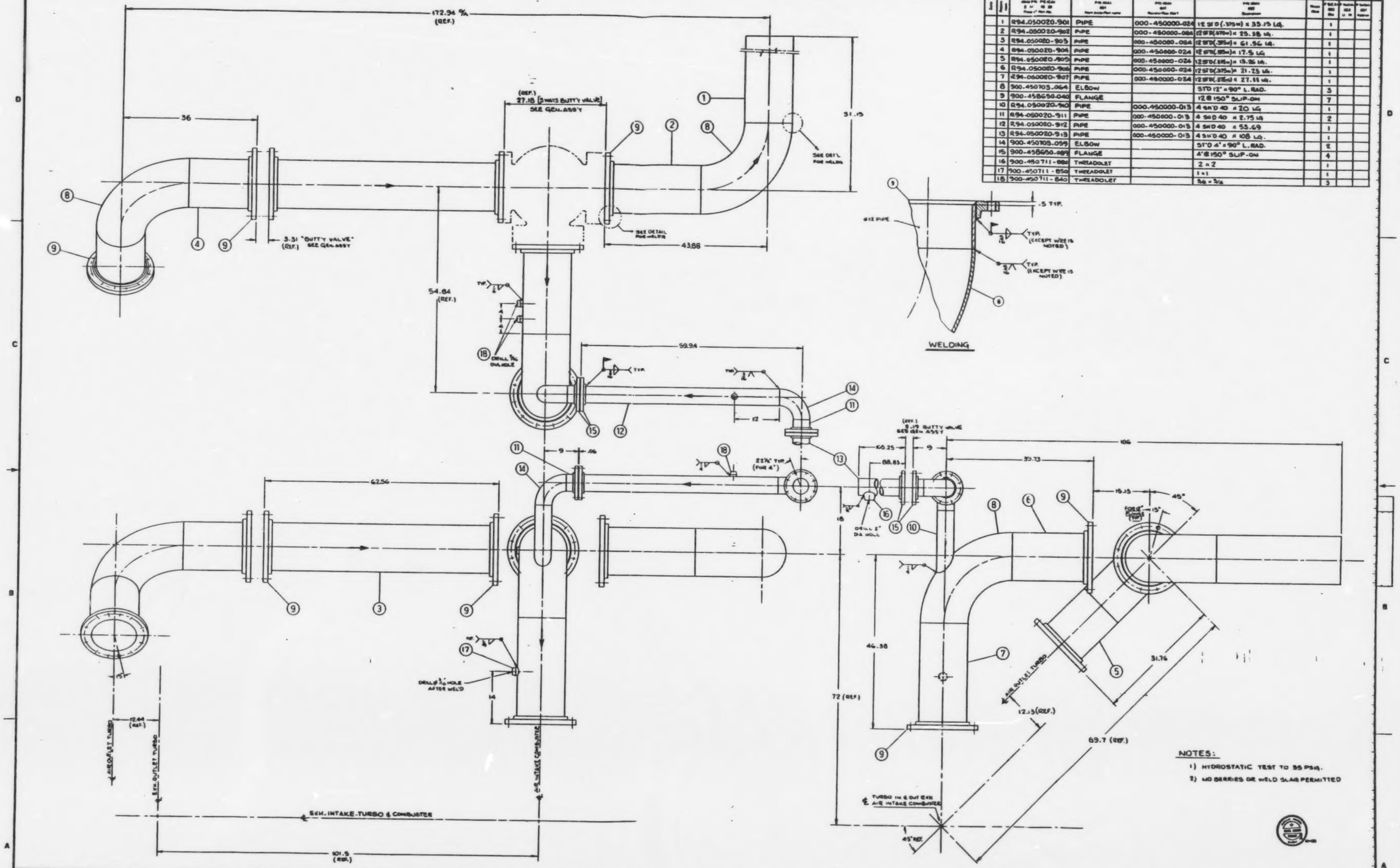
TURBOCHARGER TEST CELL FACILITY

1/1

R94-050015

FIGURE 2

		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	1	R94.050020-901	PIPE	000-450000-024	12 STD (.375w) x 33.15 LG.		1		
	2	R94-050020-902	PIPE	000-450000-084	12 STD(.375w) x 25.38 LG.		1		
	3	R94.050020-903	PIPE	000-450000-084	12 STD(.375w) x 61.56 LG.		1		
	4	R94-050020-904	PIPE	000-450000-024	12 STD(.375w) x 17.5 LG		1		
	5	R94.050020-905	PIPE	000-450000-024	12 STD(.375w) x 13.86 LG.		1		
	6	R94.050020-906	PIPE	000-450000-024	12 STD(.375w) x 21.23 LG.		1		
	7	R94-050020-907	PIPE	000-450000-024	12 STD(.375w) x 27.11 LG.		1		
	8	900-450703.064	ELBOW		STD 12" x 90° L. RAD.		3		
	9	900-458650-040	FLANGE		12 @ 150° SLIP-ON		7		
	10	R94.050020-910	PIPE	000.450000-013	4 SH'D 40 x 20 LG		1		
	11	R94-050020-911	PIPE	000-450000-013	4 SH'D 40 x 2.75 LG		2		
	12	R94.050020-912	PIPE	000-450000-013	4 SH'D 40 x 53.69		1		
	13	R94-050020-913	PIPE	000-450000-013	4 SH'D 40 x 108 LG.		1		
	14	900-450703.059	ELBOW		ST'D 4" x 90° L. RAD.		2		
	15	900-458650-089	FLANGE		4" @ 150° SLIP-ON		4		
	16	900-450711-860	THREADOLET		2 x 2		1		
	17	900-450711-850	THREADOLET		1 x 1		1		
	18	900-450711-840	THREADOLET		3/4 x 3/4		3		


172.94 (REF.)
36
(REF.) 27.18 [3 WAYS BUTTY VALVE] SEE GEN. ASSY
31.15
SEE DET'L FOR WELDING
3.31 "BUTTY VALVE" (REF.) SEE GEN. ASSY
SEE DETAIL FOR WELDS
43.88
54.84 (REF.)
DRILL 5/16 DIA. HOLE
59.94
TYP.
12
(REF.) 8.19 BUTTY VALVE SEE GEN. ASSY
60.25
9
88.83
106
35.73
19.15
45°
15°
9
.06
22½° TYP. (FOR 4")
62.56
DRILL 2" DIA. HOLE
46.38
72 (REF.)
31.76
AIR OUTLET TURBO
12.13 (REF.)
69.7 (REF.)
DRILL 3/8 HOLE AFTER WELD
14
12.44 (REF.)
AIR OUTLET TURBO
EXH. OUTLET TURBO
EXH. INTAKE-TURBO & COMBUSTER
AIR INTAKE COMBUSTER
101.5 (REF.)
℄ TURBO IN & OUT EXH. AIR INTAKE COMBUSTER
45° REF.
12 PIPE
.5 TYP.
TYP. (EXCEPT WHERE IS NOTED)
WELDING
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18

NOTES:

1) HYDROSTATIC TEST TO 35 PSIG.

2) NO BERRIES OR WELD SLAG PERMITTED

851010

C. GOURAUD

Bombardier Inc.
Division des produits ferroviaires et diesel
Rail and Diesel Products Division
Montreal Quebec Canada

R94-050018

AO

MAIN DUCTING
COMPRESSOR DISCHARGE

1/1

R94-050020

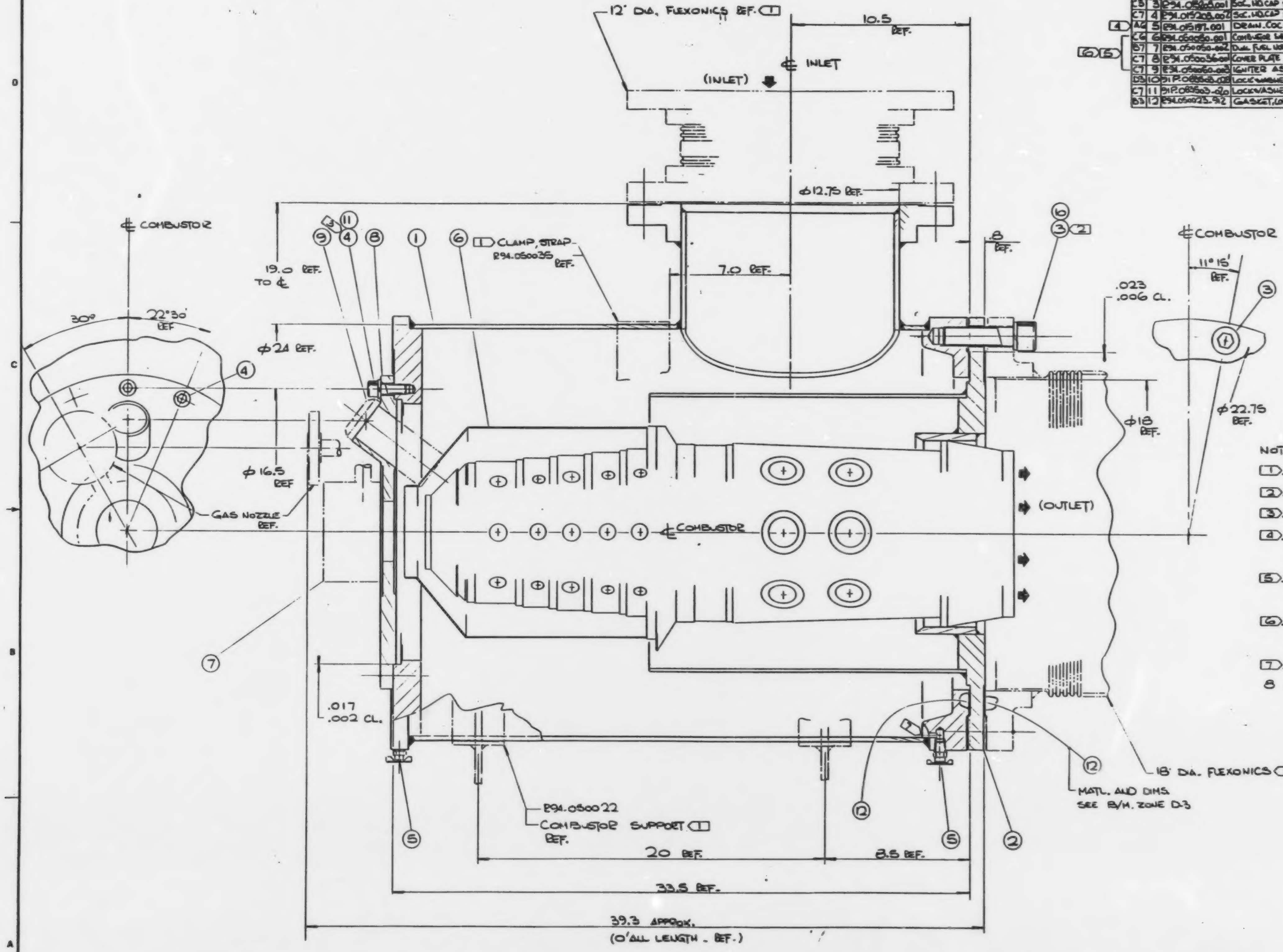
FIGURE 3

C6	1	R94.050024.001	COMBUSTOR MACH.				1		
A5	2	R94.050026.001	INNER SHELL MC				1		
C3	3	R94.050200.001	SOC. HD.CAP SCR.	STN.STL.316	1⅛-7 UNC × 4 LG.		16		
C7	4	R94.015208.007	SOC. HD.CAP SCR.	STN.STL.316	5/8-11 NC × 1.5 LG.		16		
A6	5	R94.051197.001	DRAIN.COCK		WEATHERHEAD No HO. ⅛ NPT		2		
C6	6	R94.050050.001	COMBUSTOR SUB ASSY		WESTINGHOUSE 621C856		1		
B7	7	R94.050050.002	DUAL FUEL NOZZLE A		168D861		1		
C7	8	R94.050036.001	COVER PLATE ASSY		3100A76		1		
C7	9	R94.050060.003	IGNITER ASSY		WESTINGHOUSE 359B344		1		
D3	10	91P.088503.028	LOCKWASHER	STN. STL. 304	1⅛ NOM.DIA.		16		
C7	11	91P.088503-020	LOCKWASHER	STN. STL. 304	5/8 NOM.DIA.		16		
B3	12	R94.050023.912	GASKET,COPPER	000.A10610.060	Φ18.18 × Φ20.8 × .06 THK.		2		

④ 5

⑥⑤ 6–9

CALCULATED WT. 460 Kg. APPROX.


12" DIA. FLEXONICS REF. ①
10.5 REF.
℄ INLET
(INLET)
Φ12.75 REF.
7.0 REF.
℄ COMBUSTOR
③ ⑪
⑨ ④ ⑧ ① ⑥
① CLAMP, STRAP-
R94.050035 REF.
19.0 REF. TO ℄
30°
22°30' REF
Φ24 REF.
④
Φ16.5 REF
GAS NOZZLE REF.
⑦
.017
.002 CL.
⑤
R94.050022
COMBUSTOR SUPPORT ① REF.
20 REF.
8.5 REF.
33.5 REF.
39.3 APPROX.
(O'ALL LENGTH - REF.)
℄ COMBUSTOR
(OUTLET)
.8 REF.
⑥
③ ②
.023
.006 CL.
Φ18 REF.
Φ22.75 REF.
11°15' REF.
③
⑫
⑫
⑤
②
MATL. AND DIMS. SEE B/M. ZONE D-3
18" DIA. FLEXONICS ①

NOTES.

① - SEE DWG. R94.050015 FOR NEXT ASSY

② - TORQUE TO 250 Lbs.-FT (340 Nm)

③ - TORQUE TO 160 Lbs.-FT (217 Nm)

④ - THE WEATHERHEAD COMPANY. (OR EQUIV.)
REGIONAL SALES. MONTREAL. TEL. 332.2202

⑤ - SUPPLIER. WESTINGHOUSE CANADA LTD.
HAMILTON. ONT.

⑥ - ASSEMBLY IN ACCORDANCE WITH
WESTINGHOUSE SPEC'S

⑦ - KEEP THESE (2) DRAIN HOLES CLEAN AT ASSY.

8 - ITEM-1 IN ACCORDANCE WITH "ASME"
BOILER AND PRESSURE VESSEL. SECT. VIII
AND "ACNOR" B51-M1981

DIMS. ARE INCHES

Z	86 30	ECN G-1613 INCORP.	
Y		ECN G-1621 INCORP.	

Bombardier Inc.

R94.050015

COMBUSTOR ASSY
TURBOCHARGER TEST RIG

AO

½

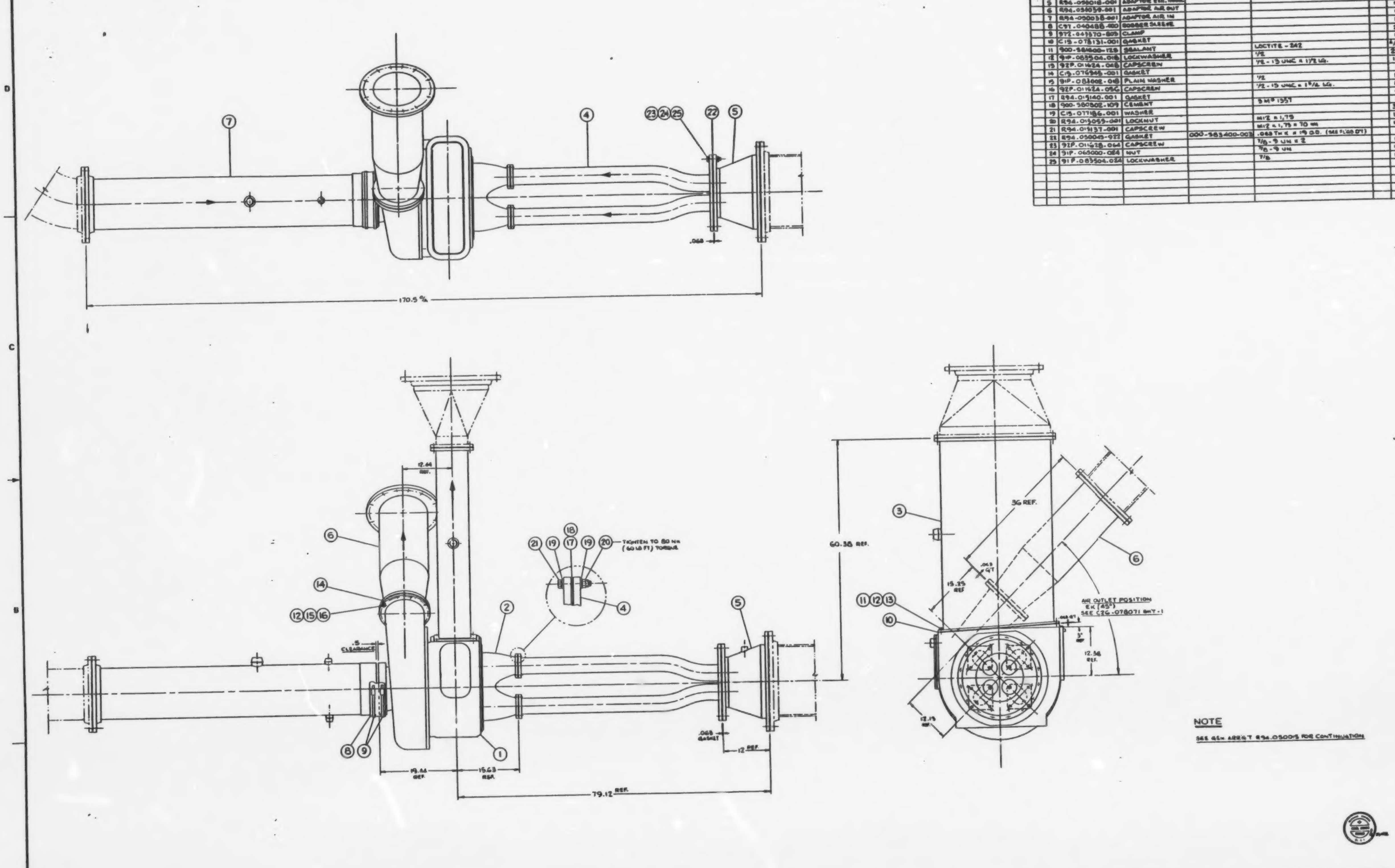
1/1

R94.050023

Y

FIGURE 4

APPENDIX "D"


7
4
23 24 25
22
5
.068
170.5 %
12.44 REF.
6
14
12 15 16
.5 CLEARANCE
18
21 19 17 19 20
TIGHTEN TO 80 N·m (60 LB FT) TORQUE
2
4
5
8 9
1
.068 GASKET
12 REF.
19.44 REF.
15.63 REF.
79.12 REF.
3
36 REF.
60.38 REF.
15.25 REF.
11 12 13
10
6
AIR OUTLET POSITION EX (45°) SEE C26-078071 SHT-1
12.38 REF.
12.19 REF.

1	C26-178068-H04	TURBOCHARGER		165 - INITIALLY	1
2	R94.036079.001	GAS INLET ASS'Y			1
3	R94.050021-001	EXHAUST			1
4	R94.050017.001	EXHAUST MANIFOLD			1
5	R94-050018-001	ADAPTOR EXH. MANI.			1
6	R94.050039.001	ADAPTOR AIR OUT			1
7	R94-050038-001	ADAPTOR AIR IN			1
8	C97.040488-400	RUBBER SLEEVE			1
9	972-047870-803	CLAMP			2
10	C13-078131-001	GASKET			1
11	900-381600-123	SEALANT		LOCTITE - 242	A/R
12	91P-083504.016	LOCKWASHER		1/2	26
13	92P.011624-048	CAPSCREEN		1/2 - 13 UNC x 1 1/2 LG.	16
14	C13.076945-001	GASKET			1
15	91P-083002-016	PLAIN WASHER		1/2	8
16	92P-011624-056	CAPSCREEN		1/2 - 13 UNC x 1 5/8 LG.	8
17	R94.019140.001	GASKET			4
18	900-380302-109	CEMENT		3M® 1357	-
19	C13-077186.001	WASHER			32
20	R94.019055-001	LOCKNUT		M12 x 1,75	16
21	R94.019137-001	CAPSCREW		M12 x 1,75 x 70 mm	16
22	R94.050045-922	GASKET	000-383400-003	.063 THK x 19 O.D. (SEE FLOOD DT)	1
23	92P.011628.064	CAPSCREW		7/8 - 9 UN x 2	12
24	91P.065000-024	NUT		7/8 - 9 UN	12
25	91P.083504.024	LOCKWASHER		7/8	12

NOTE

SEE GEN ARR'GT R94.050015 FOR CONTINUATION

Bombardier Inc.
Division des produits ferroviaires et diesel
Rail and Diesel Products Division
Montreal, Quebec, Canada

TURBO-DUCTING
SUB. ASSY
TURBO-165 (12 CYL. 4 PORT VERSION)

83-10-17
C. GIRARD
84-02-13

R94.050015

165

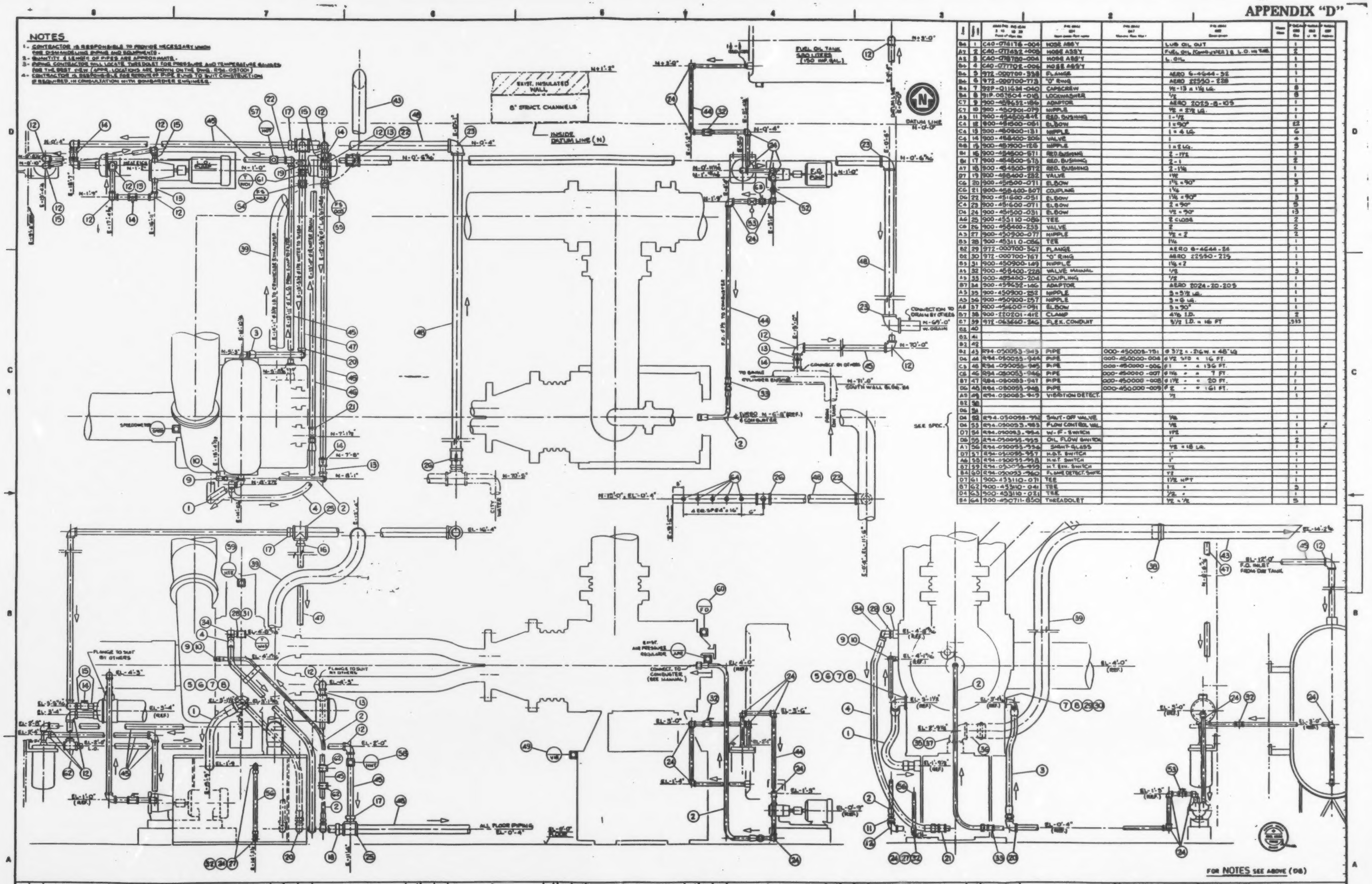
AO

R94.050043

FIGURE 5

NOTES

1. CONTRACTOR IS RESPONSIBLE TO PROVIDE NECESSARY UNION FOR DISMANTLING PIPING AND EQUIPMENTS.
2. QUANTITY & LENGTH OF PIPES ARE APPROXIMATE.
3. PIPING CONTRACTOR WILL LOCATE THREDOLET FOR PRESSURE AND TEMPERATURE GAUGES FOR THE BEST VIEW (APPR. LOCATIONS ARE SHOWN ON THE DWG. R94-057001)
4. CONTRACTOR IS RESPONSIBLE FOR REROUTE OF PIPE RUNS TO SUIT CONSTRUCTION IF REQUIRED, IN CONSULTATION WITH BOMBARDIER ENGINEERS.


FUEL OIL TANK 680 LITERS (150 IMP. GAL.)
EXIST. INSULATED WALL
8" STRUCT. CHANNELS
INSIDE DATUM LINE (N)
DATUM LINE N-0'-0"
HEAT EXCH.
SPEEDOMETER
CONNECTION TO DRAIN BY OTHERS
N-69'-0" W. DRAIN
CITY WATER
TO ENGINE CYLINDER ENGINE
N-71'-0" SOUTH WALL EL. 64
TURBO N-6'-8" (REF.) & CONDUCTER
FLANGE TO SUIT BY OTHERS
ALL FLOOR PIPING EL-0'-4"
EXIST. AIR PRESSURE REGULATOR
CONNECT TO CONDUCTER (SEE MANUAL)
EL-12'-0" F.O. INLET FROM DAY TANK
EL-14'-2¾"

Zone	Item	Part no.	Name		Description		Qty		
B4	1	C40-074176-004	HOSE ASSY		LUB OIL OUT		1		
A7	2	C40-077432-005	HOSE ASSY		FUEL OIL (CONDUCTER) & L.O. IN TUB.		2		
A3	3	C40-078700-004	HOSE ASS'Y		L. OIL		1		
B4	4	C40-077702-006	HOSE ASS'Y				1		
B4	5	972-000700-338	FLANGE		AERO 6-4644-32		1		
B4	6	972-000700-773	"O" RING		AERO 22550-228		1		
B4	7	92P-011634-040	CAPSCREW		½-13 x 1¼ LG.		8		
B4	8	91P-063504-016	LOCKWASHER		½		8		
C7	9	900-459632-186	ADAPTOR		AERO 2025-8-105		1		
C7	10	900-450901-079	NIPPLE		½ x 2½ LG.		1		
A3	11	900-454500-441	RED. BUSHING		1-½		1		
C4	12	900-451500-061	ELBOW		1 x 90°		22		
C4	13	900-450900-131	NIPPLE		1 x 4 LG.		6		
C4	14	900-458400-206	VALVE		1		4		
D8	15	900-450900-126	NIPPLE		1 x 2 LG.		5		
B1	16	900-454500-571	RED. BUSHING		2-1½		1		
B1	17	900-454500-578	RED. BUSHING		2-1		2		
A7	18	900-454500-572	RED. BUSHING		2-1¼		1		
D7	19	900-458400-232	VALVE		1½		1		
C6	20	900-451500-071	ELBOW		1½ x 90°		3		
C6	21	900-458400-807	COUPLING		1¼		1		
D6	22	900-451600-051	ELBOW		1¼ x 90°		3		
C4	23	900-451600-071	ELBOW		2 x 90°		5		
D4	24	900-451500-031	ELBOW		½ x 90°		13		
A6	25	900-455110-086	TEE		2 CLOSE		2		
C8	26	900-458400-233	VALVE		2		2		
A3	27	900-450900-077	NIPPLE		½ x 2		2		
B3	28	900-453110-086	TEE		1¼		1		
B2	29	972-000700-367	FLANGE		AERO 6-4644-24		1		
B2	30	972-000700-767	"O" RING		AERO 22550-225		1		
B3	31	900-450900-149	NIPPLE		1¼ x 2		1		
A5	32	900-458400-228	VALVE MANUAL		½		3		
A5	33	900-458400-204	COUPLING		½		1		
B7	34	900-459632-146	ADAPTOR		AERO 2024-20-205		1		
A3	35	900-450900-252	NIPPLE		3 x 3½ LG.		1		
A3	36	900-450900-257	NIPPLE		3 x 6 LG.		1		
A8	37	900-451600-091	ELBOW		3 x 90°		1		
B7	38	900-220201-412	CLAMP		4⅛ I.D.		2		
C7	39	972-063660-246	FLEX. CONDUIT		3½ I.D. x 16 FT		.333		
C2	40								
B2	41								
B2	42								
B2	43	R94-050053-943	PIPE	000-450005-751	Ø 3½ x .216W. x 48" LG		1		
D4	44	R94-050053-944	PIPE	000-450000-004	Ø ½ STD x 16 FT.		1		
C3	45	R94-050053-945	PIPE	000-450000-006	Ø 1 " x 136 FT.		1		
C6	46	R94-050053-946	PIPE	000-450000-007	Ø 1¼ " x 7 FT.		1		
B7	47	R94-050053-947	PIPE	000-450000-008	Ø 1½ " x 20 FT.		1		
D6	48	R94-050053-948	PIPE	000-450000-009	Ø 2 " x 161 FT.		1		
A5	49	R94-050053-949	VIBRATION DETECT.		½		1		
B2	50								
D6	51								
D4	52	R94-050053-952	SHUT-OFF VALVE		½		1		
D4	53	R94-050053-953	FLOW CONTROL VAL.		½		1		
D7	54	R94-050053-954	W-F-SWITCH		1½		1		
D6	55	R94-050053-955	OIL FLOW SWITCH		1"		2		
A7	56	R94-050053-956	SIGHT-GLASS		½ x 18 LG.		1		
D7	57	R94-050053-957	H.O.T. SWITCH		1"		1		
A6	58	R94-050053-958	H.W.T. SWITCH		1"		1		
B7	59	R94-050053-959	H.T. EXH. SWITCH		½		1		
B4	60	R94-050053-960	FLAME DETECT. SWITCH		½		1		
D7	61	900-453110-071	TEE		1½ NPT		1		
B7	62	900-453110-041	TEE		1 "		3		
D4	63	900-453110-021	TEE		½ "		1		
B4	64	900-450711-850	THREADOLET		½ x ½		5		

SEE SPEC. (items 52–60)

FOR NOTES SEE ABOVE (D8)

Bombardier Inc.
Division des produits ferroviaires et diesel
Rail and Diesel Products Division
Montreal Quebec Canada

PIPING ARR'G'T
L.O., F.O., WATER & EXHAUSTER
TURBOCHARGER TEST CELL FACILITY

R94-050015

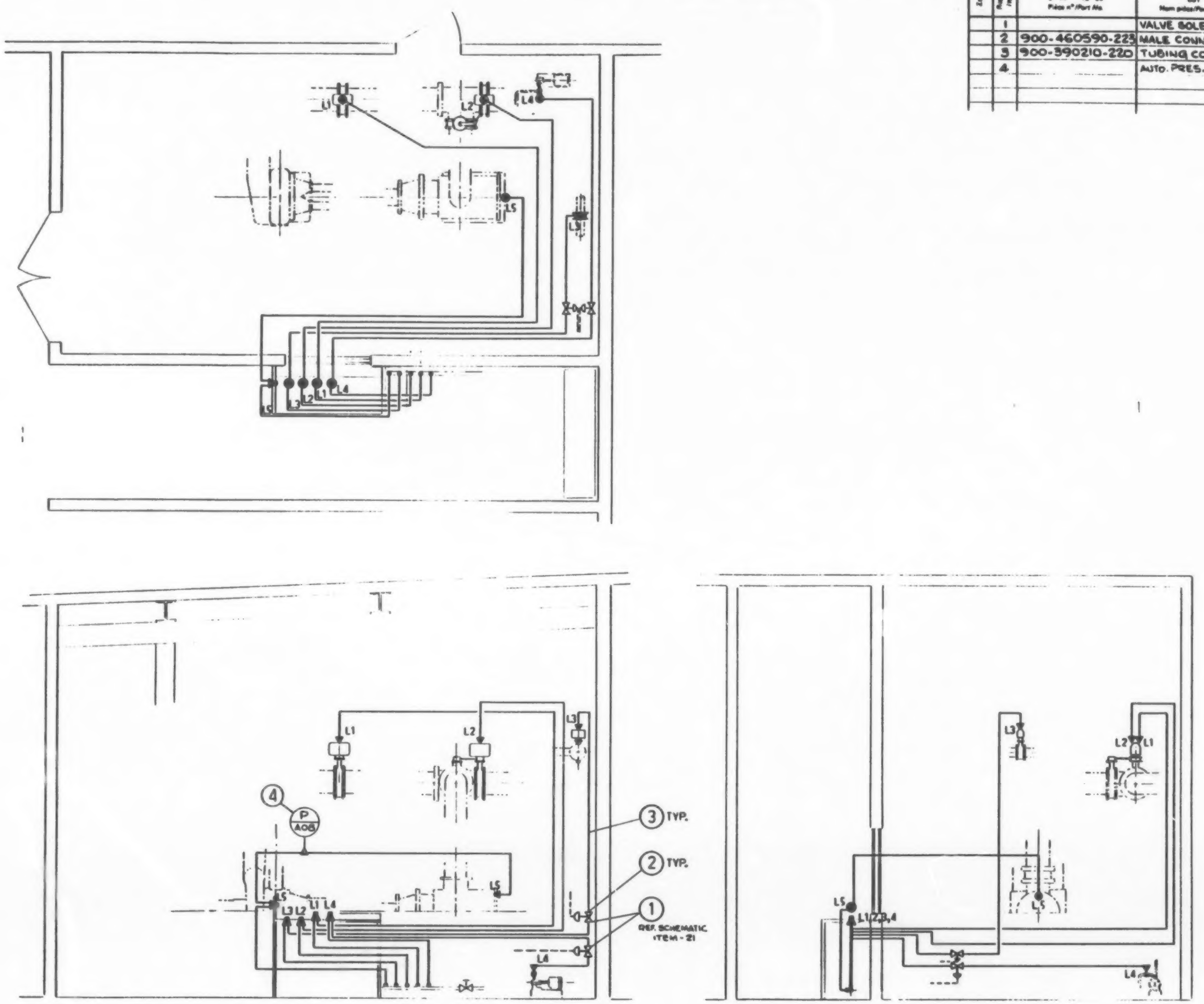
AO

R94-050053

FIGURE 6

APPENDIX "D"

Zone	Repère Item	(MA) P/N P/S (CA) 3-14 18-29 Pièce n°/Part No.	P/N (MA) 031 Nom pièce/Part name	P/N (MA) 047 Matière/Raw Mat'l	P/N (MA) 062 Description	Masse Mass	P/S (CA) 003 Qté	P/N (MA) 053 U/M	P/N (MA) 037 Approv.
	1		VALVE SOLENOID AIR	SEE SPEC.	1/4 NPT		2		
	2	900-460590-223	MALE CONNECTOR		1/4 NPT 1/4 TUBE		20		
	3	900-390210-220	TUBING COOPER		1/4 O.D. x .049 W x 200 FT		–		
	4		AUTO. PRES. GAUGE	SEE SPEC.			1		



NOTE:
CONTRACTOR IS RESPONSIBLE FOR REROUTE OF TUBE RUNS TO SUIT CONSTRUCTION & CONTROL DESK IF REQUIRED, IN CONSULTATION WHITH ENGINEER

Rév.	Zone	Description	Init°	Rév.	Zone	Description	Init°	Rév.	Zone	Description	Init°	Rév.	Zone	Description	Init°

Dessinateur M.MCH.
Date 860211
Vérificateur C. GOURAUD
Date 860219
Ch. groupe
Date 86 02 26
Date 86 03 26

PROJECTION
TOLÉRANCE ET FINI DE SURFACE SAUF INDICATION CONTRAIRE
MÉTRIQUE 000 ± 0.5 / 000.0 ± 0.05 / 000.00 ± 0.005
IMPÉRIAL 0 - 12" / 12"+
FRAC (MACH.) ± 1/32 ± 1/16
DÉCIMAL ± .005 ± .010
FRAC (BRUT) ± 1/16 ± 1/8
ANGLES ± 1/2° CHANFREIN ± 2°
ÉBARBER 1/64" / 0.4mm MAX.
FINI DE SURFACE 125 mu in / ▽▽

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N° référence
N° ensemble/Assembly No R94.050015
N° modèle
A1
N° commande/Sales Order No
Éch./Sc. NTS
Folio 1/1

Bombardier Inc.
Division des produits ferroviaires et diesel
Rail and Diesel Products Division
Montréal, Québec, Canada

Objet/Subject
PNEUMATIC CONTROL
TUBING ASS'Y
TURBOCHARGER TEST CELL FACILITY
Plan N°/Drawing No R94-050058

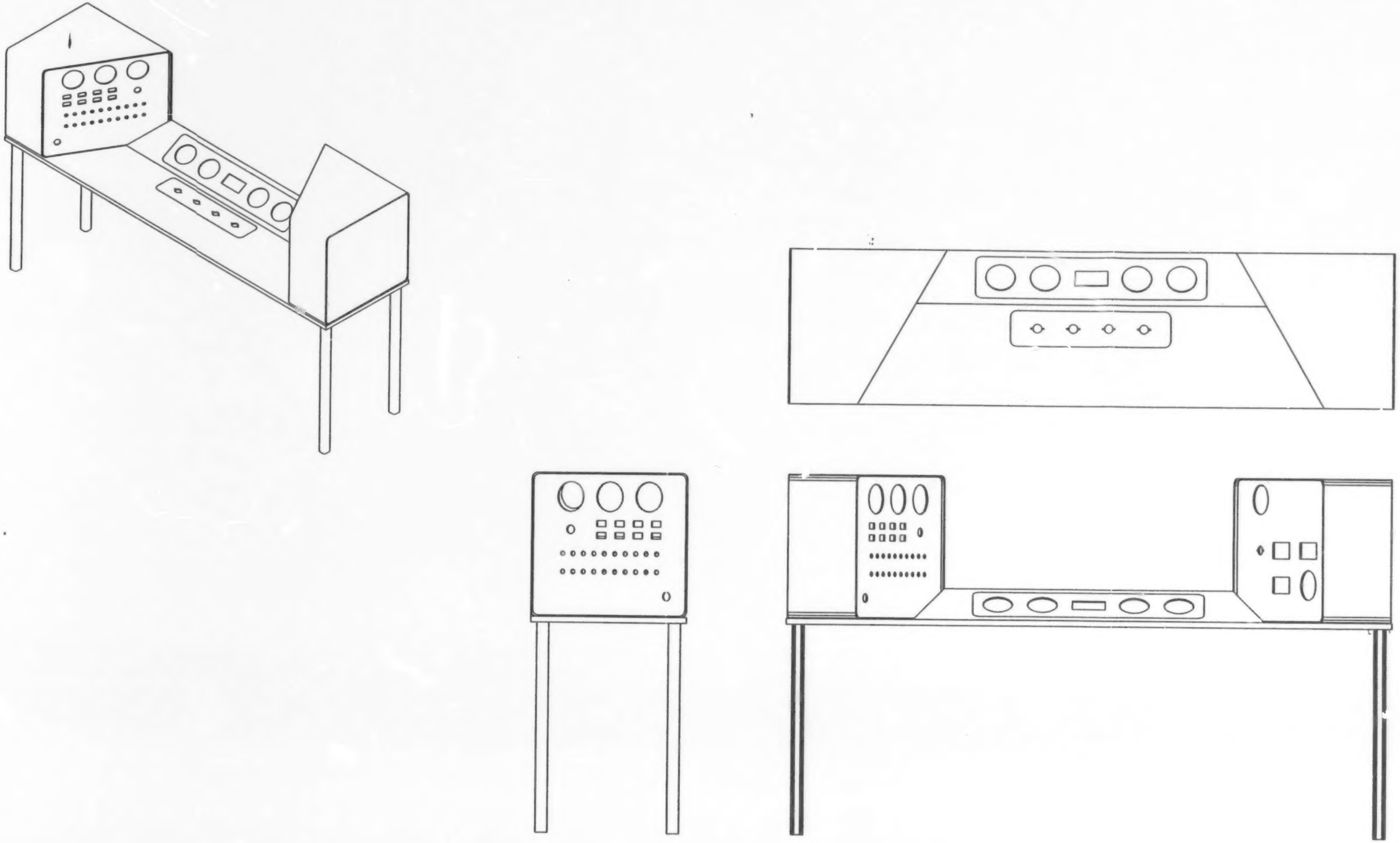
FIGURE 7

(MA)-P/N-P/SION 3-6 10-29 Pieza n° / Part n°

P/N (MA) 001 Nom pieza / Part name

P/N (MA) 047 Materia / Raw Mat'l

P/N (MA) 062 Description



M.MTCH.
860314

PROJECTION

TOLERANCE ET FINI DE SURFACE
SAUF INDICATION CONTRAIRE
DEC.(MACH.) 000 = +/- 0.03
000.0 = +/- 0.02
000.00 = +/- 0.01
000.000 = +/- 0.005
DEC.(BRUT.) +/- .06
ANGLES: +/- 1/4 DEG. CHANFREIN +/- 2 DEG.
EBARDER 1/64
FINI DE SURFACE 125 MU IN.

R94-050057

R94-050015

A1

1/4

BOMBARDIER INC.
DIVISION DES PRODUITS FERROVIAIRES ET DIESEL
RAIL AND DIESEL-PRODUCTS DIVISION
MONTREAL, QUEBEC, CANADA

CONTROL DESK ARR'G'T
TURBOCHARGER TEST CELL FACILITY

R94-050060

-

FIGURE 8

APPENDIX "E"

BASELINE PERFORMANCES

Fig. 1	1-B2400	Run-in and test report
Fig. 2	1-251	Run-in and baseline performance charts
Table E-1		1-251 Operating guide

APPENDIX "E"
FIGURE 1

PROJECT NO 484431

REPORT NO. ERD/07/85

Bombardier Limitée
Rail and Diesel Products Division
MONTREAL CANADA

~~CONFIDENTIAL~~

DIESEL ENGINEERING

ENGINE RESEARCH AND DEVELOPMENT GROUP

SUBJECT 1-B2400 RUN-IN & PRELIMINARY TESTS

COMPILED BY: J.P. Dowell

APPROVED BY: R.M. Dunton,
Director
Engine R&D
& Diesel Engineering

Work done by: G. Bérubé
J. Bourassa
D. Brown
S. Kandiah
A. Schomak

APPROVED BY:

DISTRIBUTION

SUMMARY

FULL REPORT
S.P. Syngal
Engine R&D Circ.
R.D. Smalley
M.L. Payne
File

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Preliminary Running 3

Exhaust System Tuning Tests 4

Friction Measurement Tests 5

Preliminary Performance Results 7

CONCLUSION AND RECOMMENDATIONS 7

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Figure 2 - Exhaust Pressure Diagram from 6-251 ii
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Figure 4 - 1-B2400 Exhaust Back Pressure Test iv
Figure 5 - Effect of LTENIN on 1-B2400 v
Figure 6 - 1-B2400 Willan's Line vi
Figure 7a- 1-B2400 Baseline -Proplaw vii
Figure 7b- 1-B2400 Baseline -Proplaw viii

INTRODUCTION

The 1-B2400 engine has been assembled and installed in Test Cell #4 of Building 65. This report will present the sequence of events and results of the run-in and initial performance tests.

Start-Up and Run-In

The engine was started on 850318 and ran for about 10 minutes at idle. Those covers fitted with an adhesive-backed strip gasket were leaking so these were removed and replaced by silicone sealant. A 3/16" spacer was added at the flange between the camshaft section and the cam gear drive shaft to obtain better axial alignment between the oil holes in camshaft and the cam bearings. A 2 1/2" NPT fitting was welded to the drive-end of the oil sump so that the oil suction line to the oil pump could be increased in diameter and decreased in length. This was done to minimize suction restriction and subsequent cavitation and vibration of the oil pump. A sheet steel deflector was welded to the right side gear cover to prevent oil from being thrown up into the crankcase exhauster suction hose. When re-fitting the fuel cam to the camshaft, the fuel cam split axially between the cam surface and the threaded hole (see figure 1). The cracks were caused by high hoop stress created during assembly of the cam onto the tapered collar. Loctite RC-680 was used to permanently hold the cam and collar to the shaft and the tightening bolts were removed. This 'fix' has not failed after 126 hours. The fuel cam was positioned at 4.5mm lift at 18° BTDC and the timing shims adjusted for 18° BTDC. The valve timing was adjusted to 'zero' markings and measured timing was as follows: EVO-122.7°, EVC-412.4°, AVO-297.0°, AVC-566.9°, Overlap-115.4° (all timings are top of ramp). The instrumented cylinder head (Pmax, Pexh) and instrumented injector (Pinj, NL) 9x155x0.38 were fitted. The compression ratio was measured at 11.81:1.

Start-Up and Run-In (cont'd)

The engine was restarted on 850402 and the run-in procedure given in Appendix A was started. At the 110 kW at 800 rpm point the exhaust elbow and bellows vibrated badly. A "quick and nasty" bracket was added to the elbow and this reduced vibration significantly. At the 40 kW at 900 rpm point the engine vibration became excessive. The rubber isolation pads between the skid and siezmic mass were removed. The grub plates holding down the skid were doubled up and the engine/dyno were re-aligned. This reduced vibration significantly but levels were still high.

Further measurement and analysis lead to the conclusion that the skid is simply too flexible. A new skid is presently being designed and is yet to be procured and installed. Nevertheless, the run-in procedure continued until the overspeed trip went off at 40 kW at 1000 rpm. Over the next few weeks numerous adjustments were made to the overspeed trip including changes in spring stiffness and pre-load but without success. Since the overspeed is driven by the balance shaft at twice engine speed, the flyweight had been machined out to reduce its mass. However, this reduced the eccentric mass to the point where the flyweight was almost balanced by the adjusting screw and nut making it practically impossible to adjust the tripping speed. In the end, the overspeed was dis-engaged and we now rely on the electronic overspeed trip.

After the run-in was completed, the power assembly was removed and inspected. All components were in excellent condition except the big end upper bearing showed signs of fretting between the insert and rod. This suggests that an increase in nip is required but for the time being the fretting will be monitored closely. All components were replaced except the oil control ring which had been damaged during removal. Additional support was added to the air and exhaust receivers in the test cell and a bracket was added to the exhaust elbow and bellows.

Preliminary Running

Since the engine was running well, the next few weeks were spent making adjustments to the test cell and de-bugging instrumentation. This involved fine tuning of the dyno load controller, engine speed governor, boost pressure control valve, air temperature controller, jacket water and lube oil temperature control valves and the dyno water inlet pressure controller. During this period, the Endevco injection pressure transducer blew apart. The transducer was replaced while the damaged one has been sent back under warranty. The Kistler 6211 cylinder pressure transducer melted down and caused water to leak into the engine. The head was removed and the oil changed. Inspection of the head and transducer indicated that the copper seal between the transducer and cylinder head flame deck (water side) had failed allowing gas to blow-by and overheat the transducer. The cylinder head had been incorrectly machined such that the seat width for the copper seal was quite narrow. A new transducer and two copper seals were fitted and testing proceeded. This temporary measure seems to be working while a new head is being machined.

The filters on the boost air supply had to be removed and cleaned several times presumably because of the old pipes leading to Building 65. Also, the water trap kept plugging so it was removed and a small valve which is always open was fitted to drain condensation.

The engine was operated over the load and speed range of a typical turbocharged engine to ensure that the controllers were functioning correctly.

Exhaust System Tuning Tests

Up to this point in the test program, the engine had been operating with little or no exhaust back-pressure. Although this gives good performance, it is not a realistic representation of a typical turbocharged engine where the exhaust manifold and turbine offer a significant back-pressure. The object of tuning the exhaust system is to approximate the pulse shape and back-pressure of a multi-cylinder turbocharged engine. In this case, we are attempting to simulate the 3-pulse manifold of the 12-B2400. A typical exhaust pressure diagram taken from the 6-251 at full load is shown in figure 2. The 6-251 has a 3-pulse manifold and this served as a guideline in the tuning tests. An exhaust pressure transducer was installed in the port of 1-B2400 cylinder head. (Same location used for 6-251 readings).

Ricardo DP82/1667 provides a very good explanation of the various exhaust system configurations that can be used for single cylinder versions of turbocharged engines. In Test Cell 4 we have a system comprising of orifice plate followed by plenum receiver followed by butterfly valve and then silencer. The orifice size can be changed to alter the duration and height of the exhaust pulse and the butterfly valve position can be used to control the overall back-pressure.

By trial and error the orifice size was selected. The original butterfly valve had too much clearance leakage so a tighter fitting valve was installed. Figure 3 shows the correctly adjusted exhaust pressure diagram. Figure 4 shows the effect of the overall exhaust back-pressure (controlled by butterfly valve) on engine performance at full load. It should be noted that the back-pressure quoted here is not the mean back-pressure as measured by, say, a manometer but rather, it is the base pressure from the exhaust pressure diagram. The exhaust pressure diagram will be measured on the 12-B2400 and the 1-B2400 adjusted accordingly.

Friction Measurement Tests

Since the single cylinder engine has more bearings and gears per cylinder than the multi-cylinder, one would expect the friction losses on the single to be proportionately larger. However, the single cylinder has independently driven pumps which reduces auxiliary losses. In short, the friction on the single cylinder must be measured and correlated with the multi in order that performance figures can be comparable.

The friction on the single cylinder has been measured by the use of accurate indicator diagrams. For this discussion, the following terms are defined:

$$\text{TMEP} = \int_{0^\circ}^{720^\circ} p\,dV \quad .... \quad \text{Thermodynamic MEP}$$

$$\text{IMEP} = \int_{180^\circ}^{540^\circ} p\,dV \quad .... \quad \text{Indicated MEP}$$

PMEP = TMEP - IMEP .... Pumping MEP

FMEP = TMEP - BMEP .... Friction MEP

Nmech = BMEP/TMEP .... Mechanical Efficiency

Note: '0' crank angle is at TDC scavenge.

It should be noted that this definition of FMEP and Nmech includes the PMEP (positive or negative). Because the single has a lower mechanical efficiency than a multi, the effect of lube oil temperature on fuel consumption will be more pronounced on the single. Figure 5 shows the effect of LTENIN on BSFC, Nmech, and LPENIN. This figure shows the mechanical efficiency to be 81.8% at 80°C LTENIN and the strong influence of temperature on efficiency is evident.

Friction Measurement Test (cont'd)

A conservative estimate of the friction in a modern multi-cylinder medium speed diesel puts the mechanical efficiency at approximately 90%. It is quite difficult to measure the friction under actual operating conditions in any engine. Motoring the engine does not take into account firing pressures or real pumping work. Indicator diagrams are practical on the single but extremely expensive and of dubious accuracy on a multi since each cylinder must be measured. Willan's Line is a convenient method of estimating the friction on a multi-cylinder engine but again it does not account for firing pressures. Figure 6 compares the Willan's Line taken from the 1-B2400 and 6-251. It can be seen that by this method of measurement, the 1-B2400 friction is about 27% higher than the 6-251.

The implication of higher friction on the single means that for the same indicated power, the single must operate at a lower 'rated' brake power. Hence, the 'rated' brake power of the 1-B2400 for a corresponding 12-B2400 rating of 205kW/cyl. is calculated using the Nmech from indicator diagrams as follows:

$$205 * \frac{0.817}{0.900} = 186 \text{ kW}$$

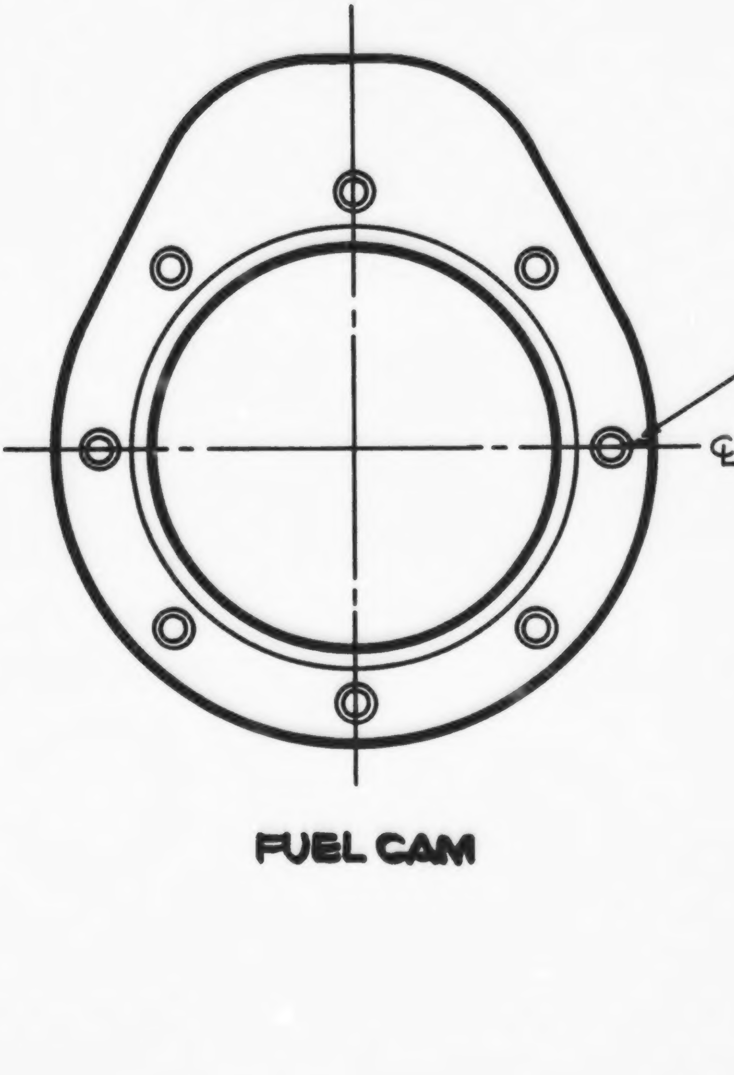
where the multi-cylinder mechanical efficiency is assumed to be 90%. Furthermore, any brake specific performance parameters (eg., bsfc) must be corrected for the difference in friction before comparison with multi-cylinder performance can be made.

APPENDIX "A"

1-B2400 RUN-IN SCHEDULE

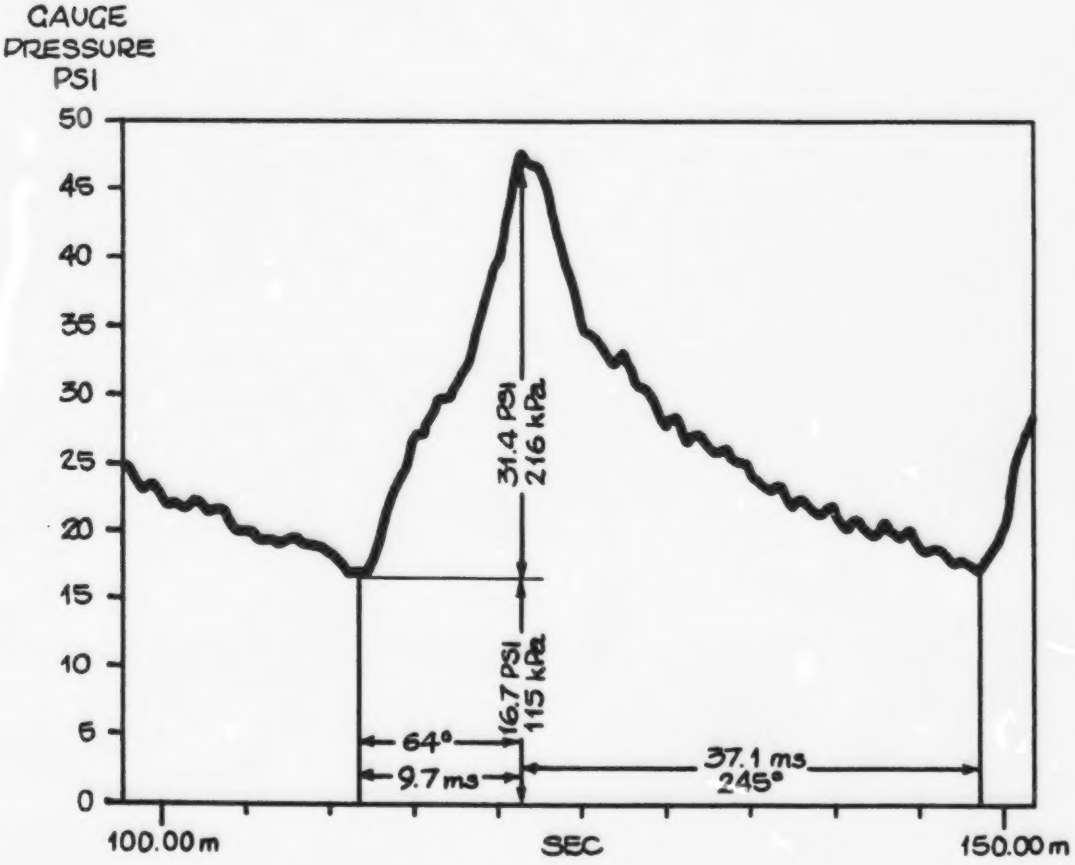
TIME [hrs]	SPEED [rpm]	POWER [kW]	BMEP [bar]	TORQUE [daNm]	BOOST PRESSURE [kPa]	OIL FLOW [%]	WATER FLOW [%]	AIR TEMP [C]
0.2	400	5	1.23	12	0	30	27	30
Stop, remove covers, visual check, check tappets.								
0.8	400	20	4.91	48	2	30	27	35
1	600	20	3.27	32	2	40	40	35
1	600	40	6.55	64	8	40	40	40
1	800	40	4.91	48	8	49	54	40
1	800	80	9.82	95	32	49	54	50
1	800	110	13.51	131	60	49	54	57
1	900	40	4.37	42	8	54	61	40
1	900	80	8.73	85	32	54	61	50
1	900	120	13.1	127	72	54	61	59
1	1000	40	3.93	38	8	59	68	40
1	1000	80	7.86	76	32	59	68	50
1	1000	120	11.79	115	72	59	68	59
1	1000	150	14.74	143	112	59	68	67
1	900	80	8.73	85	32	54	61	50
1	1100	120	10.72	104	72	63	75	59
1	1100	160	14.29	139	128	63	75	69
0.5	1100	205	18.31	178	210	63	75	80
Stop, remove, strip and examine power assembly and mains.								

FIGURE 1



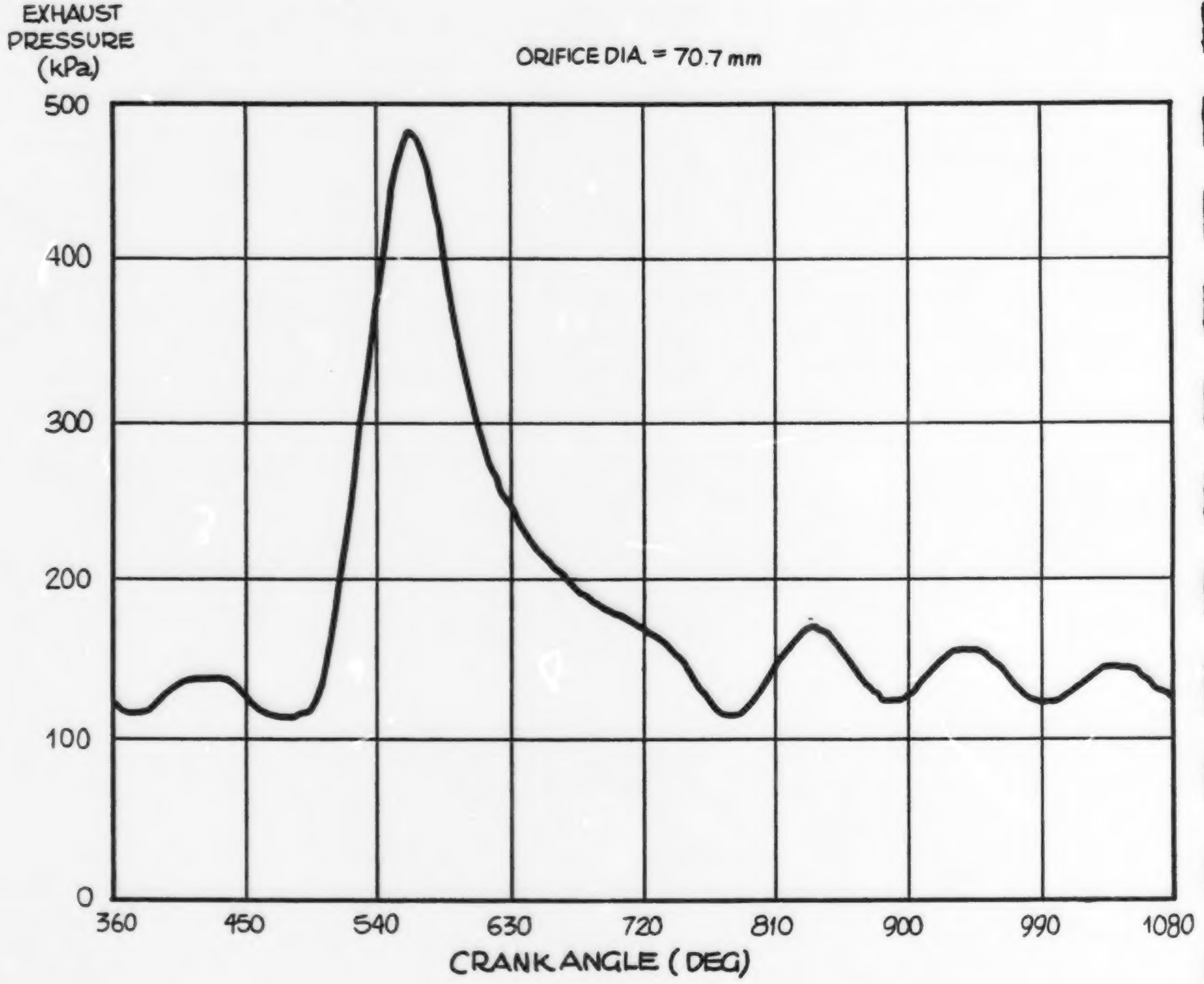
FUEL CAM

FIGURE 2



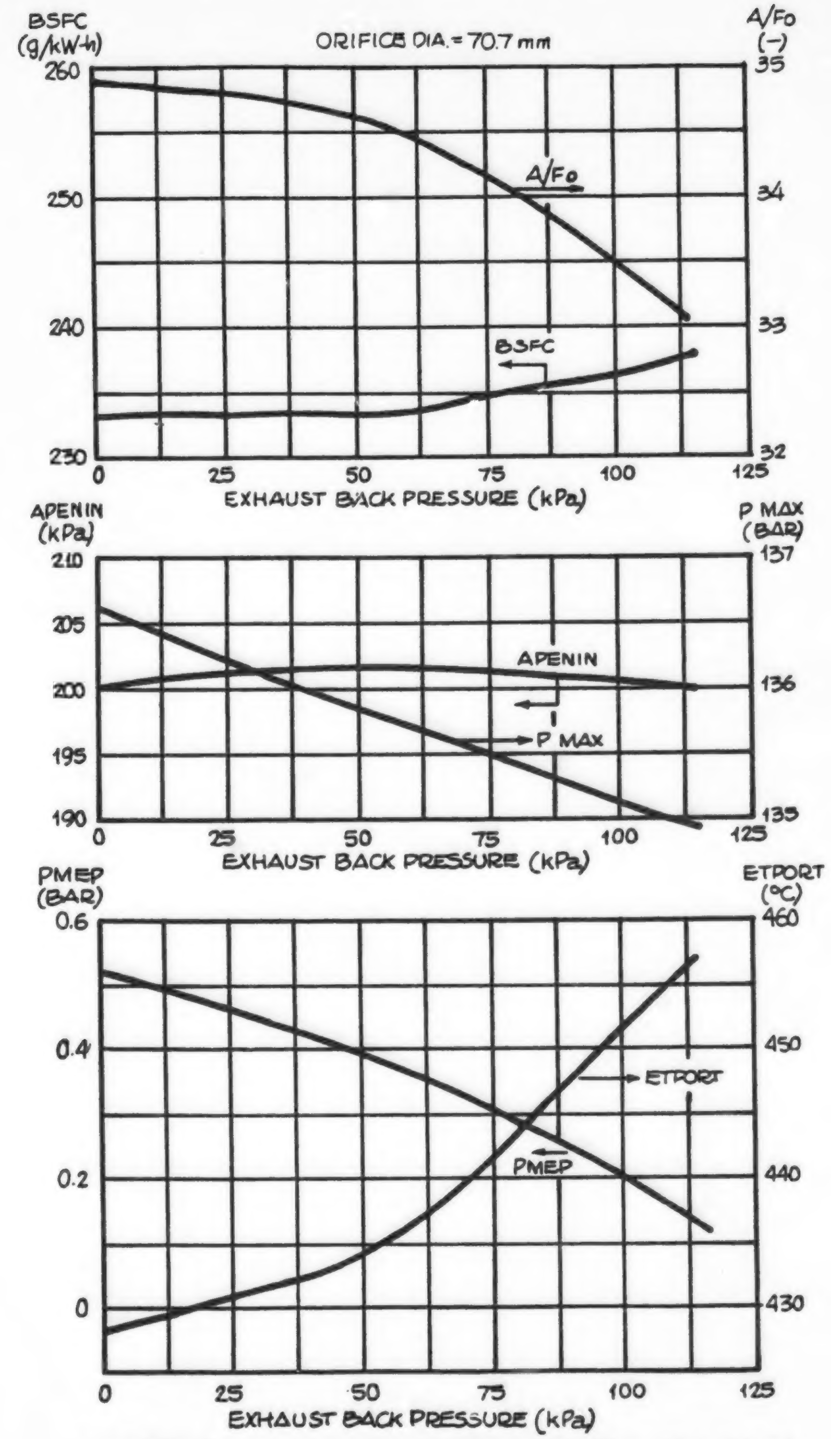
EXHAUST PRESSURE DIAGRAM
FROM 6-251 - 1500 BHP @ 1100 RPM

FIGURE 3



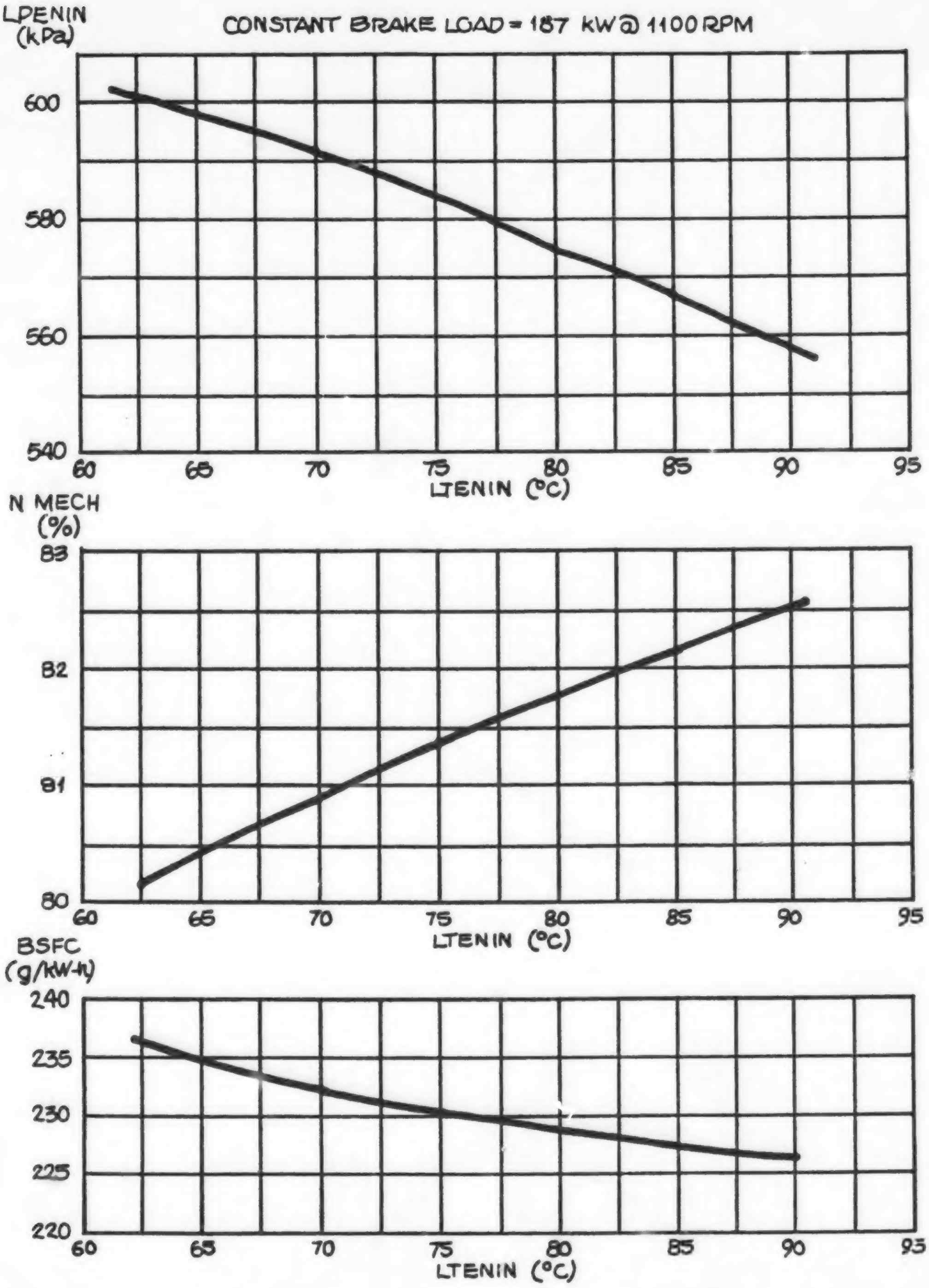
EXHAUST PRESSURE DIAGRAM
FROM 1-B2400-187 LW @ 1100 RPM

FIGURE 4

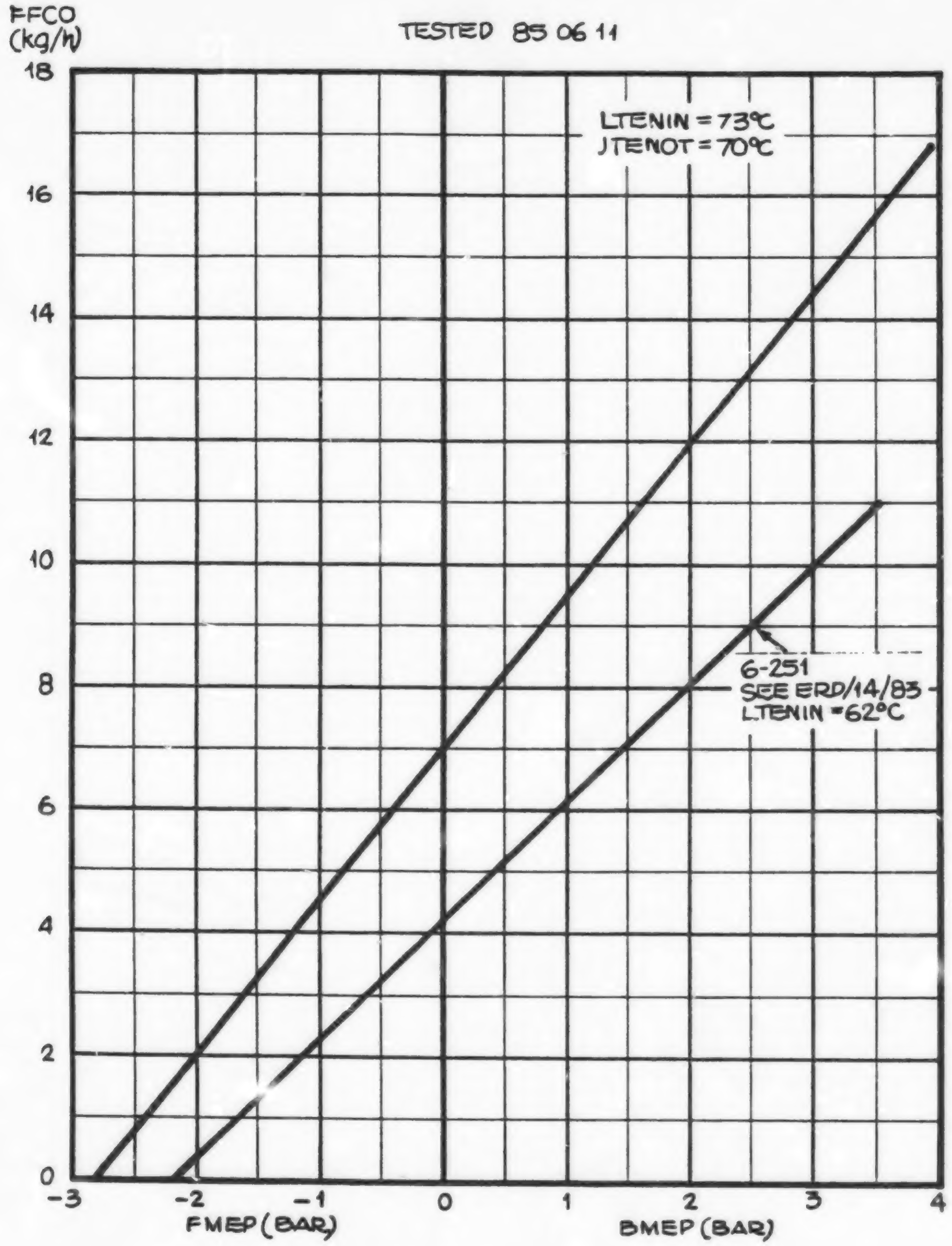


1-B2400 EXHAUST BACK PRESSURE TEST – 85 06 11

FIGURE 5

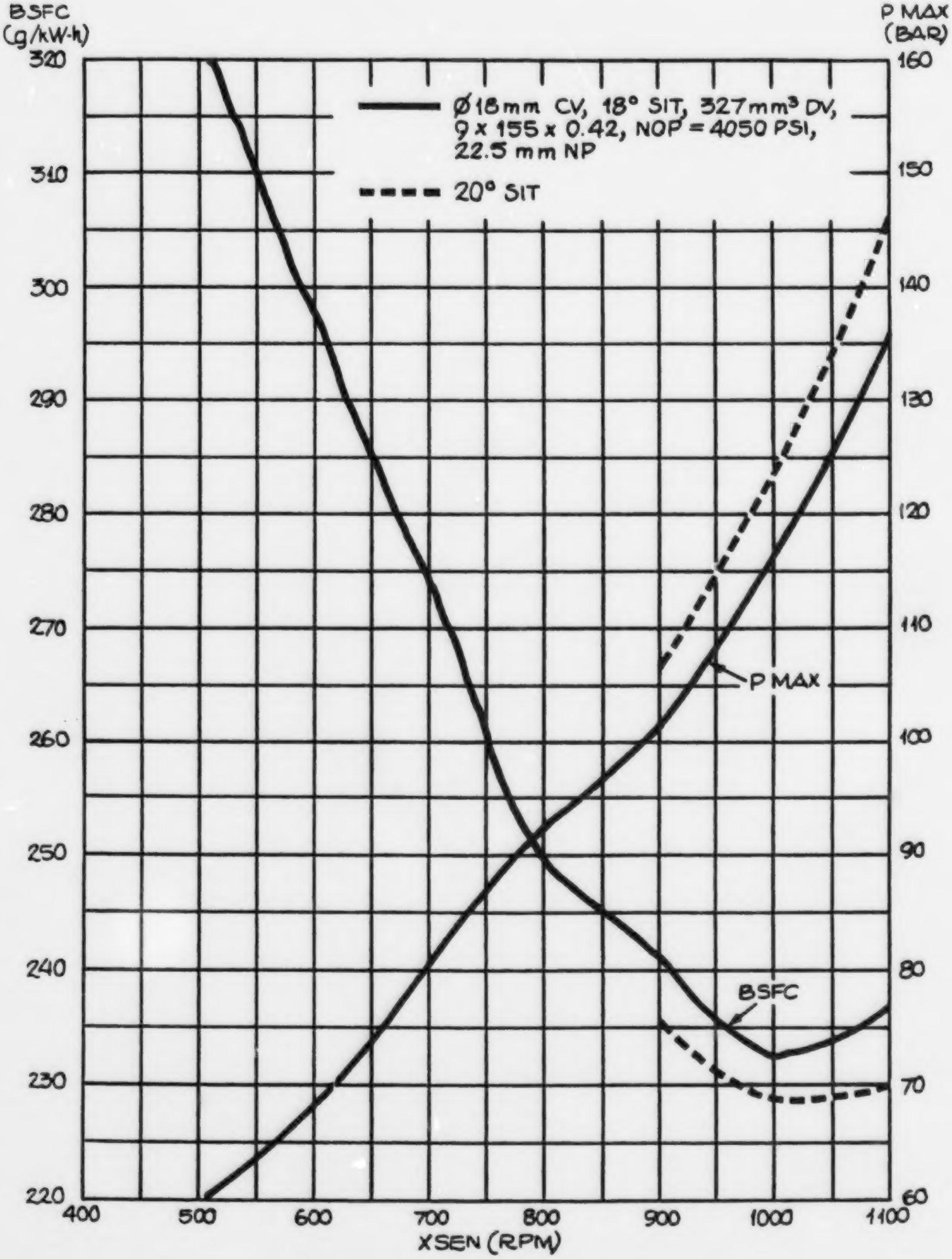

CONSTANT BRAKE LOAD = 187 kW @ 1100 RPM

EFFECT OF LTENIN ON 1-B2400



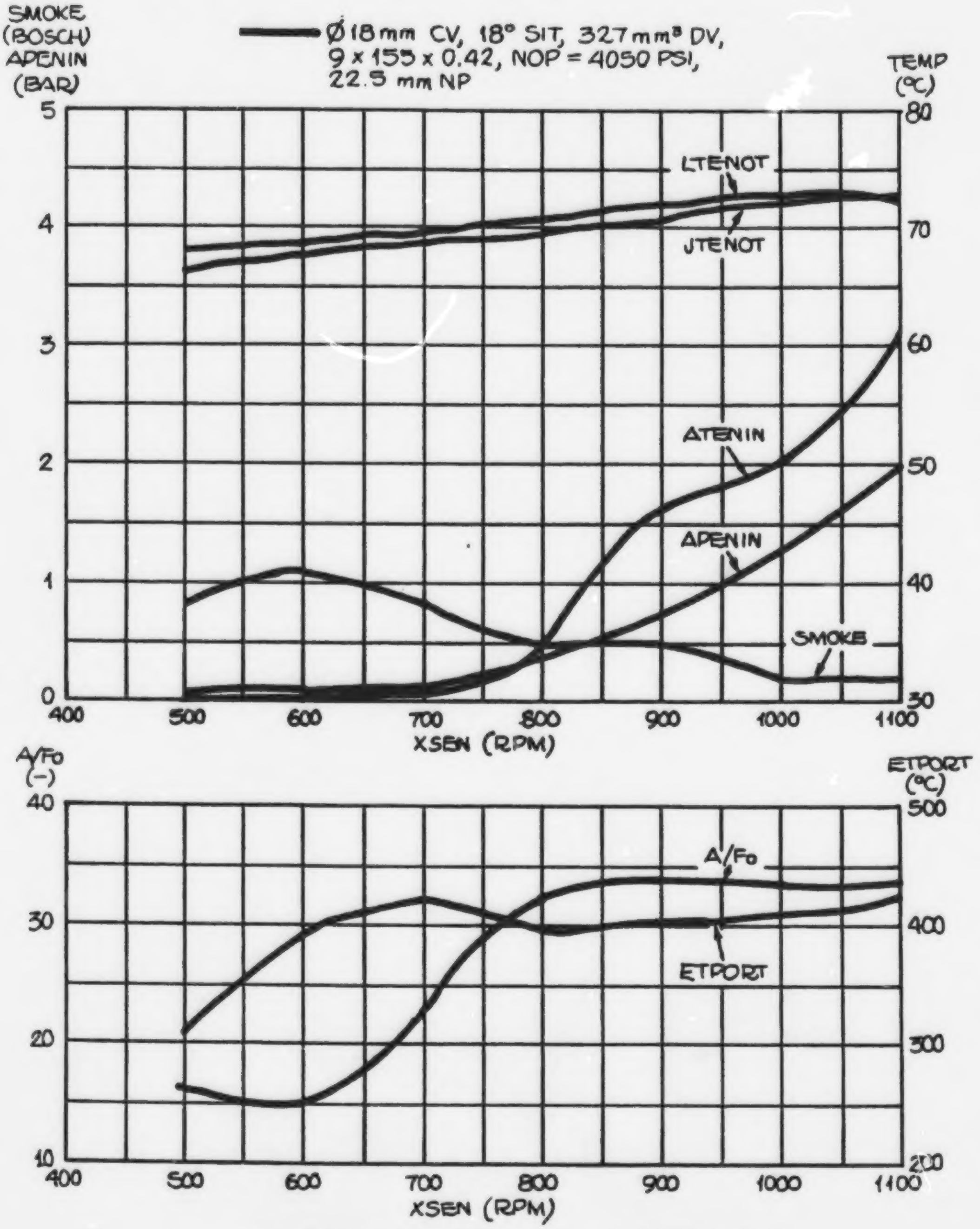
1-B2400 WILLAN'S LINE – 1100 RPM

FIGURE 7A



1-B2400 BASELINE — PROPLAW

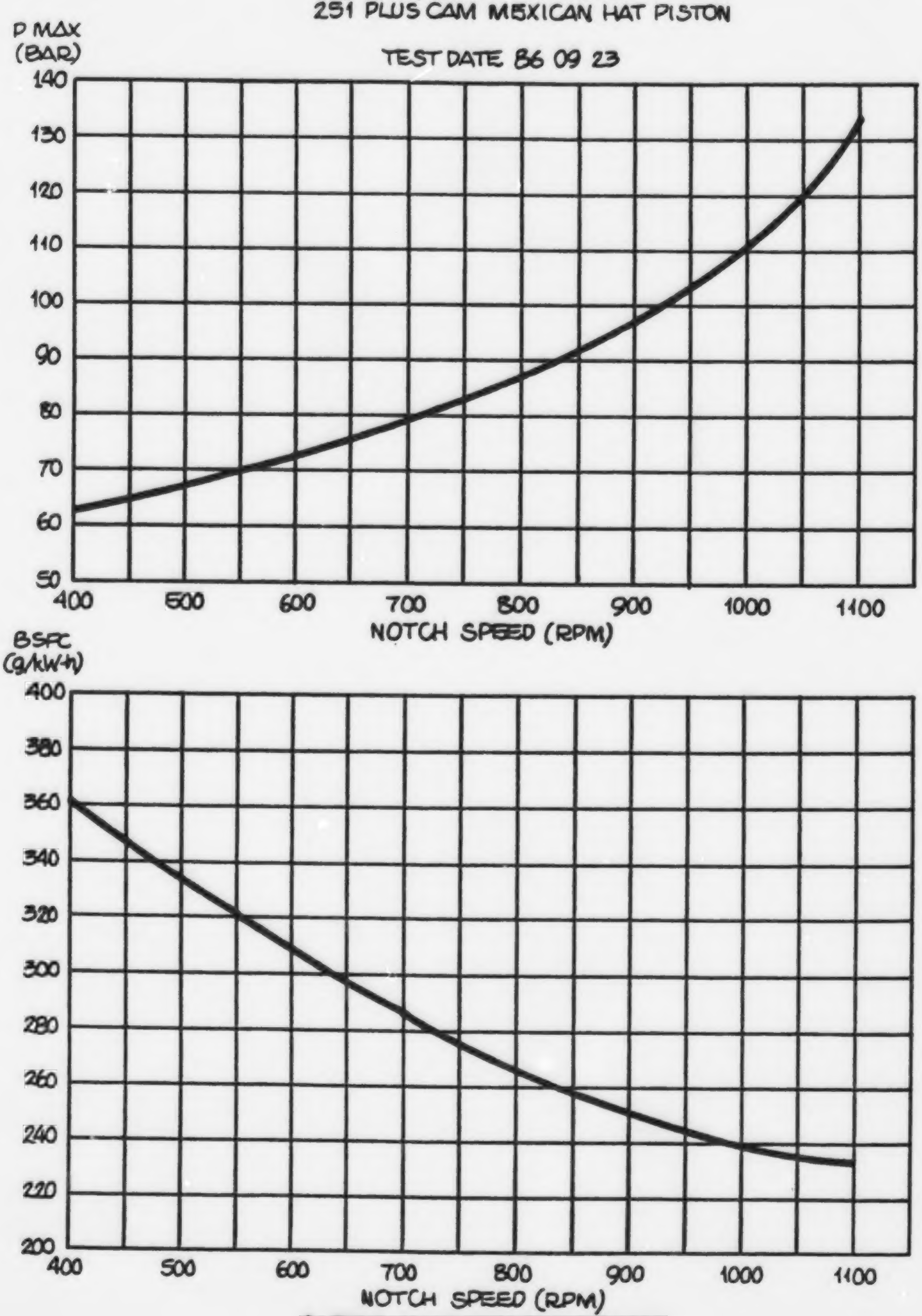
FIGURE 7B



1-B2400 BASELINE—PROPLAW

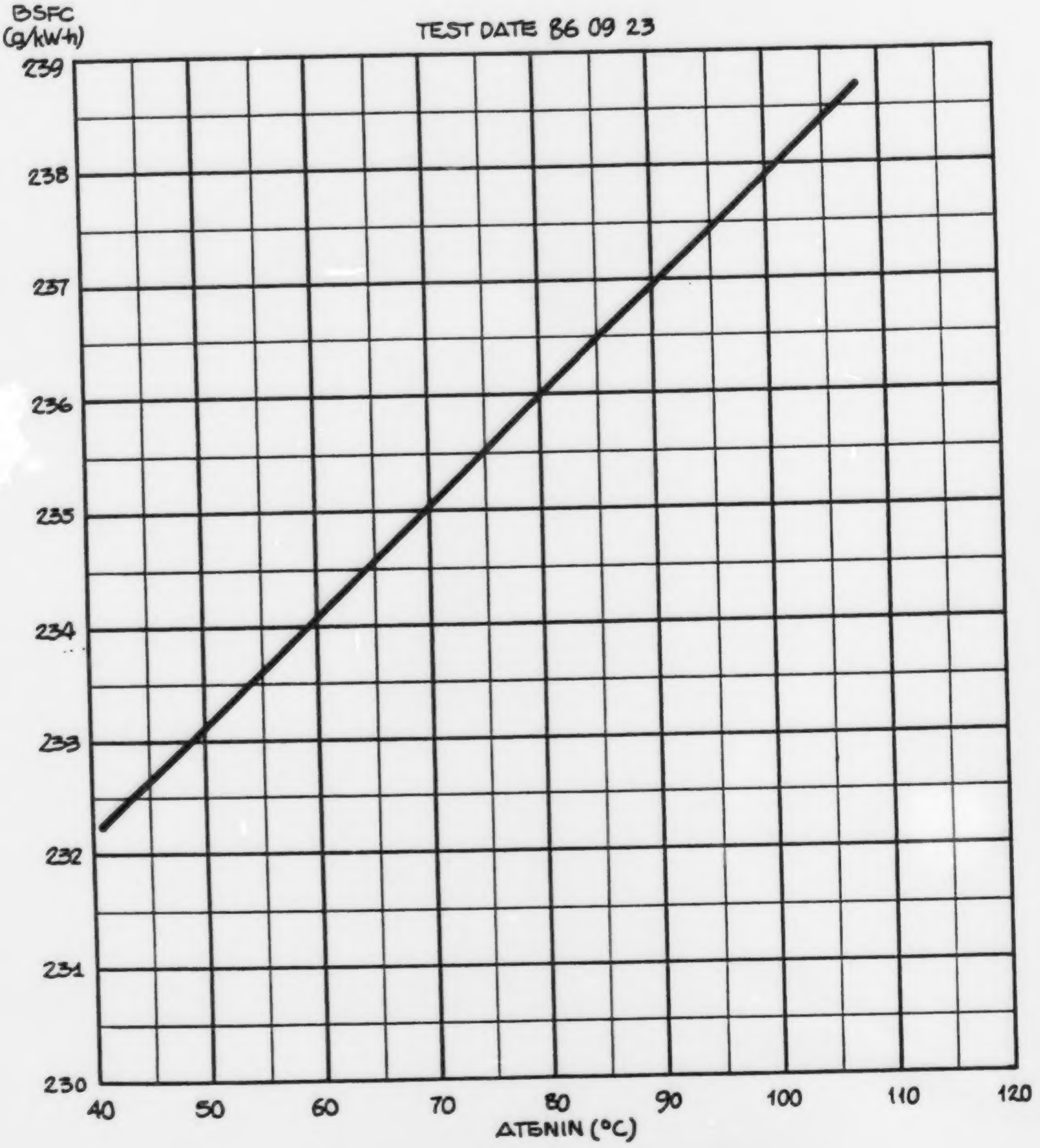
9 x 4 Ø x 145° NOZZLE
22° BTDC TIMING
169.5 kW/CYL @ 1100 RPM
251 PLUS CAM MEXICAN HAT PISTON

TEST DATE 86 09 23



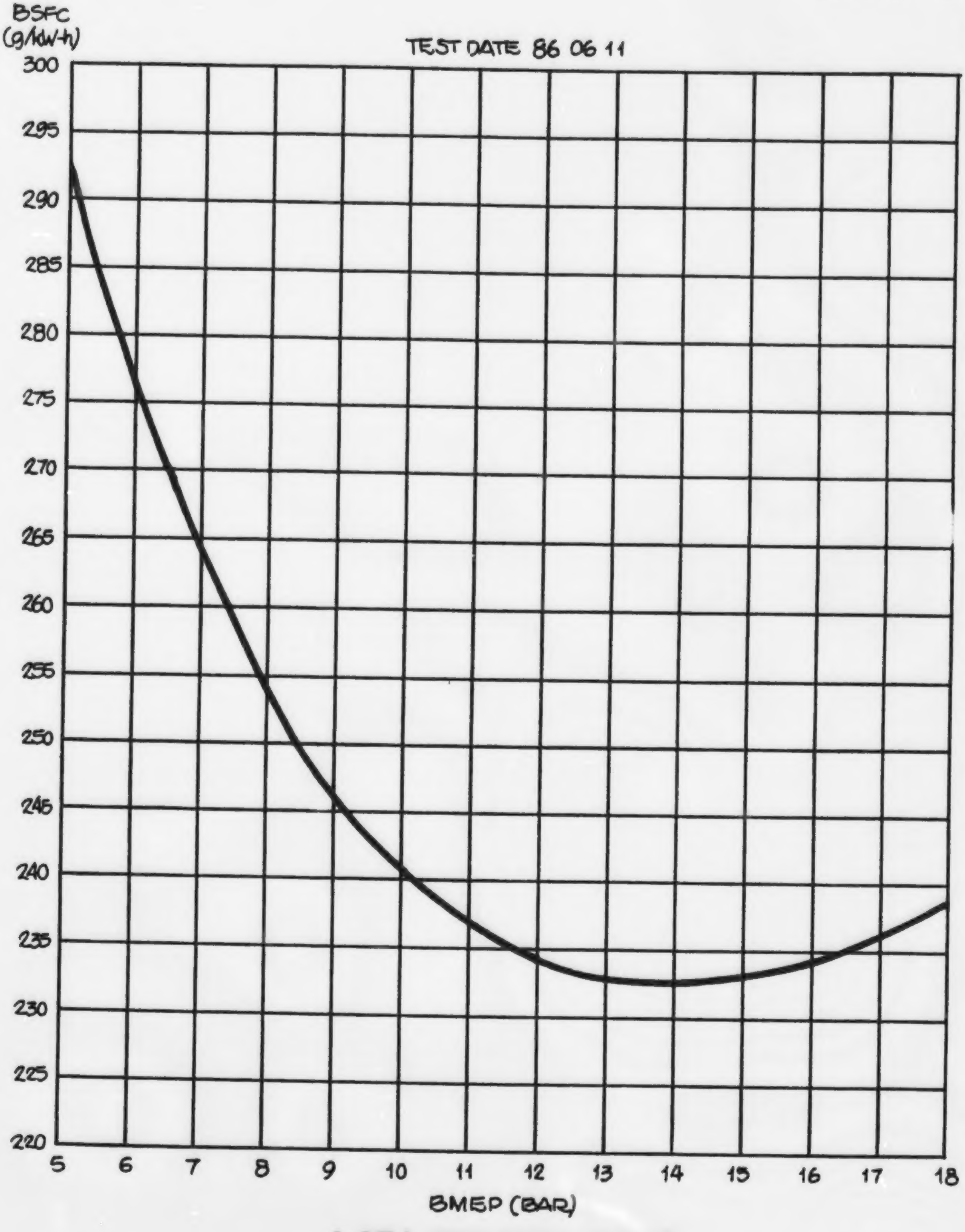
1-251 PERFORMANCE

FIGURE 2.1



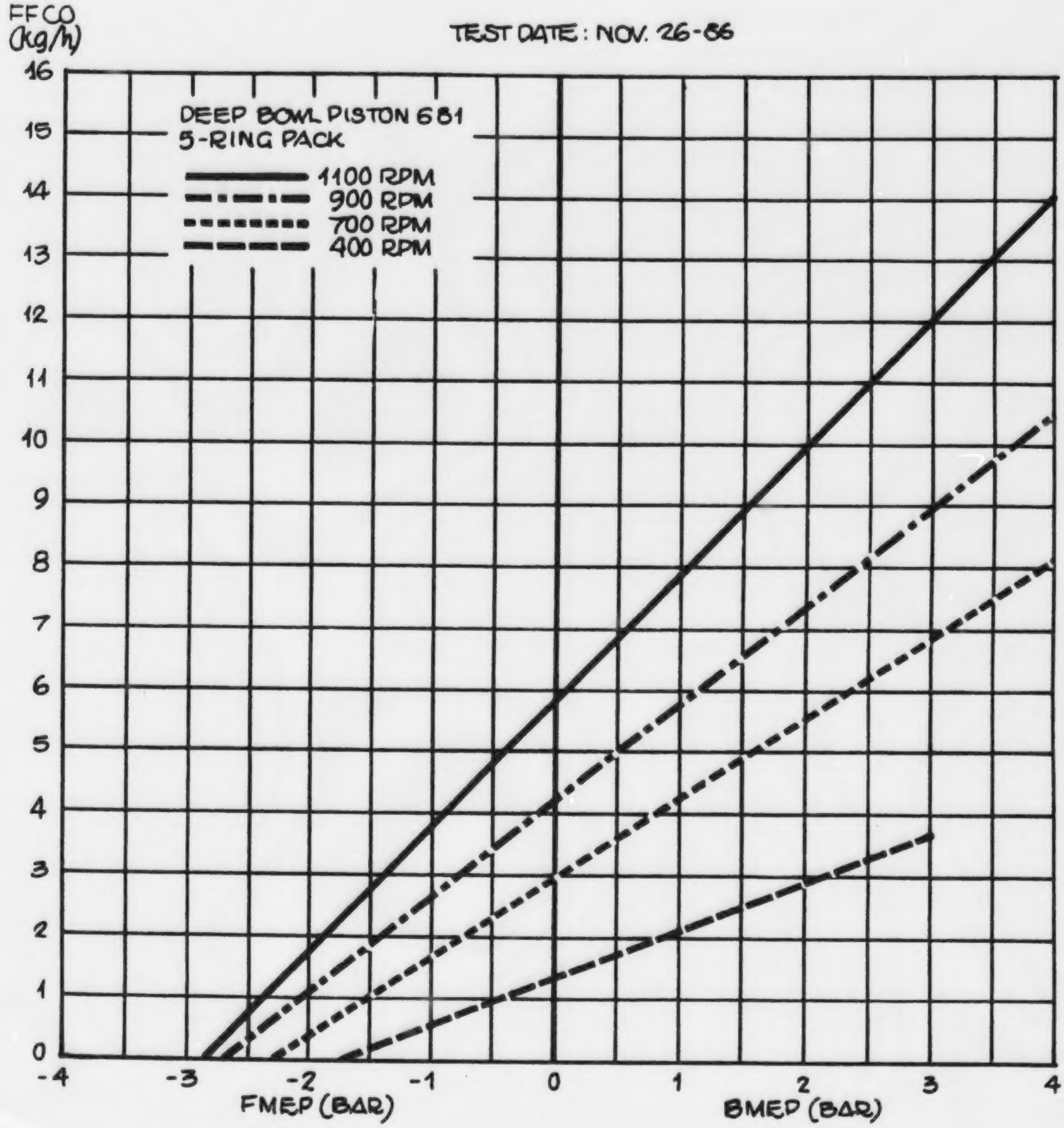
1-251 PERFORMANCE
EFFECT OF INTAKE AIR TEMPERATURE
186 kW @ 1100 RPM

FIGURE 2.2



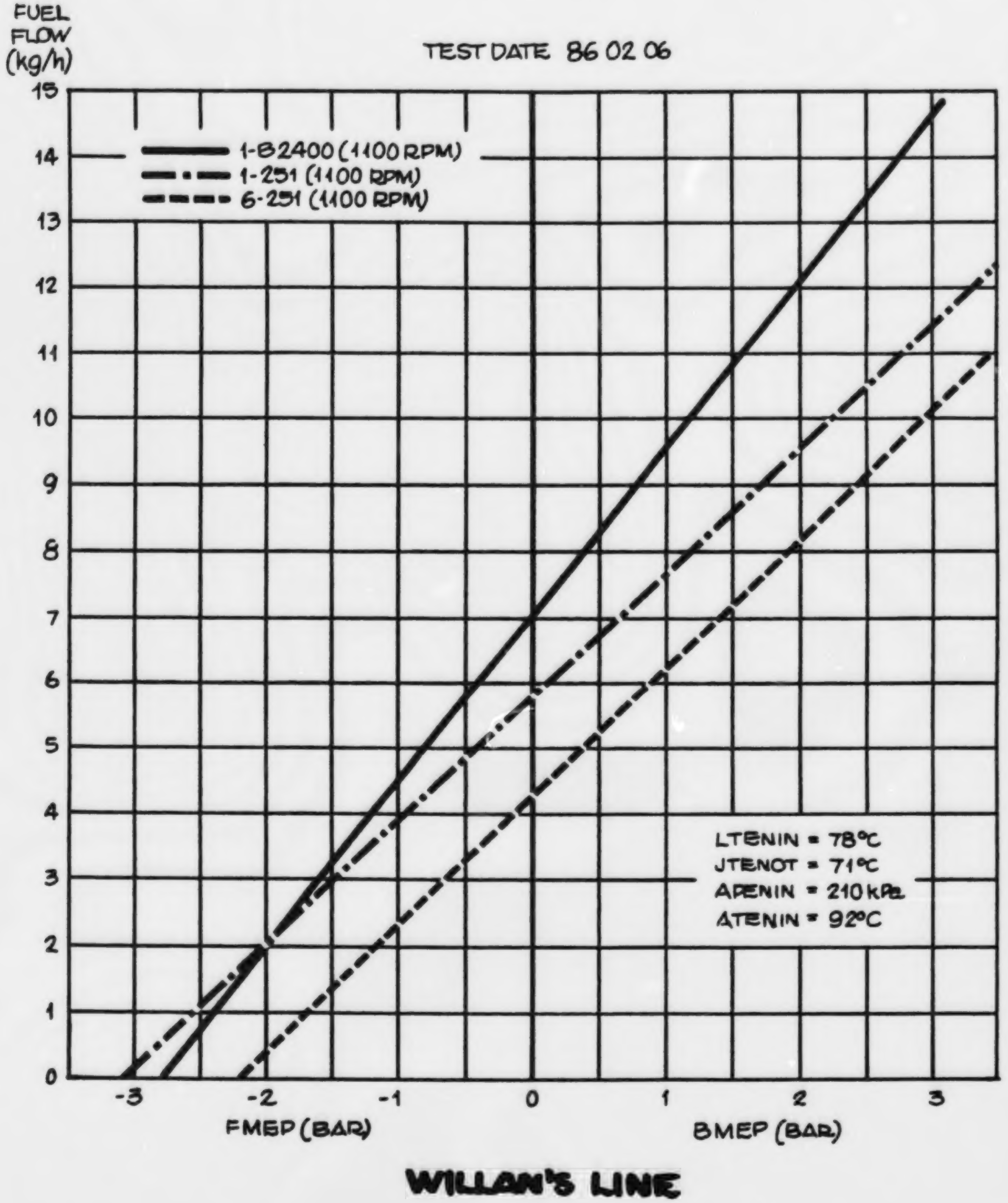
**1-251 PERFORMANCE
1200 RPM**

FIGURE 2.3



1-251 PERFORMANCE
WILLAN'S LINE

FIGURE 24



WILLAN'S LINE

FIGURE 2.5

TABLE E-1

1-251 OPERATING GUIDE

ENGINE SPEED [MIN^{-1}]	TORQUE [NM]	OUTPUT POWER [KW]	-ATENIN- BOOST AIR TEMP. [°C]	BOOST AIR PRESS. [KPA]				
400	214	9.0	45°C	10				
500	334	17.5	45°C	10				
600	481	30.2	50C	15				
700	654	48.0	55°C	25				
800	855	71.7	65°C	40				
900	1082	102.1	75°C	70				
1000	1336	140.0	85°C	130				
1100	1616	186.4	95°C					

*	SET POINT	LIMIT
LPPPOT	800 Kpa	1000 Kpa
LTENIN	80 oC	90 °C
JTENOT	75 °C	85 °C
APENIN	as required	250 Kpa
ATENIN	as required	105 °C
ETENOT	-----	550 °C
FPPPOT	300 Kpa	500 Kpa
LT Across	engine	10 °C
JT Across	engine	5 °C

* See Key to mnemonics Appendix "A" Fig. 4-A1